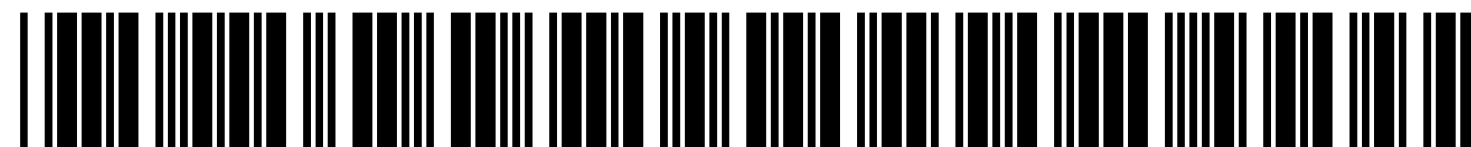

US007242823B2

(12) **United States Patent**
Karashima et al.

(10) **Patent No.: US 7,242,823 B2**
(45) **Date of Patent: Jul. 10, 2007**

(54) **OPTICAL TRANSMISSION CHANNEL BOARD, BOARD WITH BUILT-IN OPTICAL TRANSMISSION CHANNEL, AND DATA PROCESSING APPARATUS**

(75) Inventors: **Seiji Karashima**, Osaka (JP); **Seiichi Nakatani**, Osaka (JP); **Yasuhiro Sugaya**, Osaka (JP); **Toshiyuki Asahi**, Osaka (JP); **Takashi Ichiryu**, Osaka (JP)

(73) Assignee: **Matsushita Electric Industrial Co., Ltd.**, Osaka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/041,101**

(22) Filed: **Jan. 21, 2005**

(65) **Prior Publication Data**

US 2005/0196095 A1 Sep. 8, 2005

(30) **Foreign Application Priority Data**

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Jan. 22, 2004	(JP)	2004-014966
Jan. 22, 2004	(JP)	2004-014968

(51) **Int. Cl.**
G02B 6/12 (2006.01)
H01L 29/00 (2006.01)

(52) **U.S. Cl.** **385/14**; 385/49; 257/499

(58) **Field of Classification Search** 385/14, 385/49

See application file for complete search history.

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Primary Examiner—Michelle Connelly-Cushwa
Assistant Examiner—Rhonda S. Peace
(74) *Attorney, Agent, or Firm*—RatnerPrestia

(57) **ABSTRACT**

An optical transmission board is provided. The optical transmission board includes an optical transmission channel, a retention board for retaining the optical transmission channel and circuit patterns. The circuit patterns are formed on the retention board and a part of the circuit patterns is used as an electric circuit. The optical transmission channel is positionally regulated by the part of the circuit patterns.

8 Claims, 45 Drawing Sheets

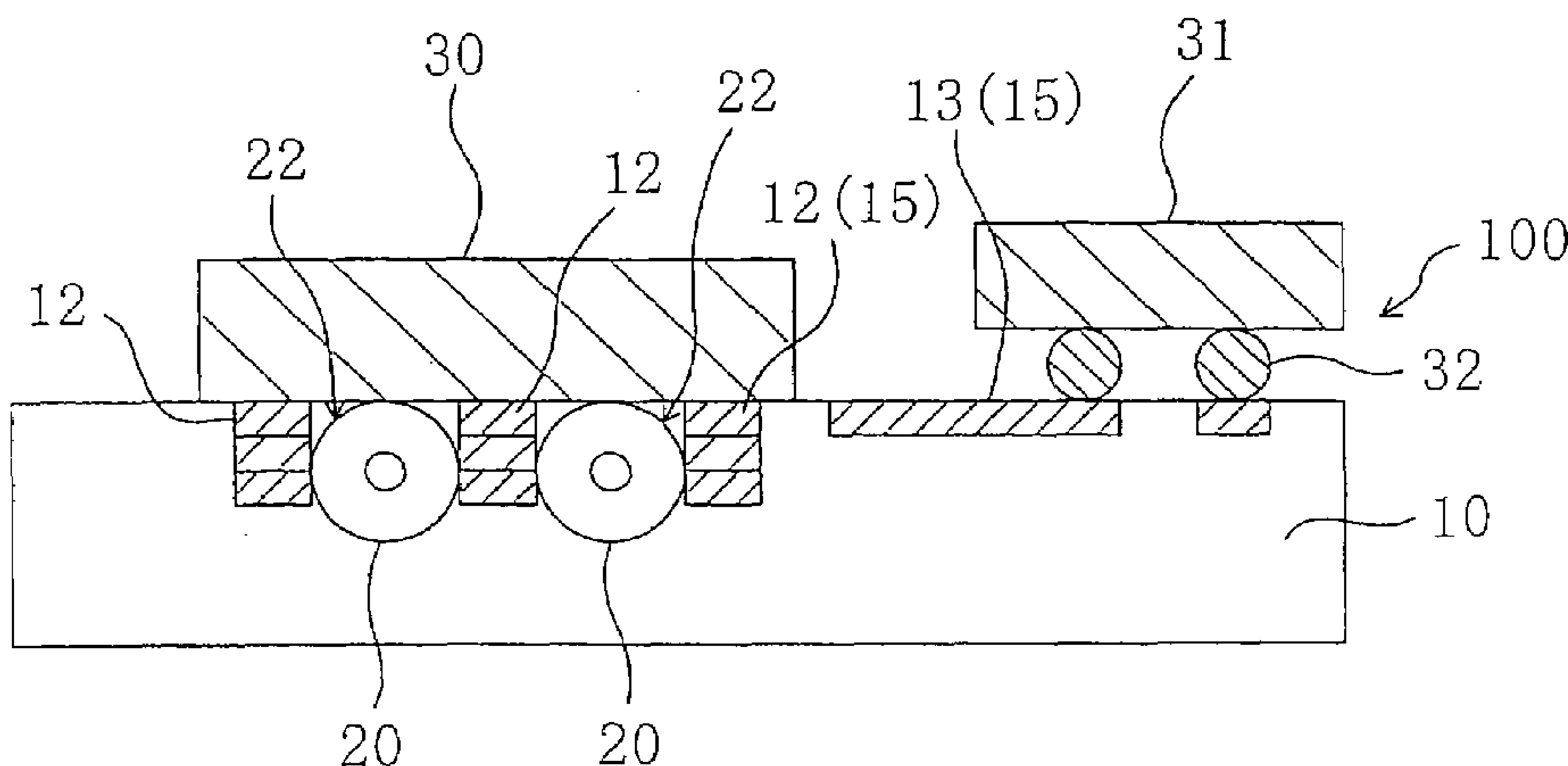
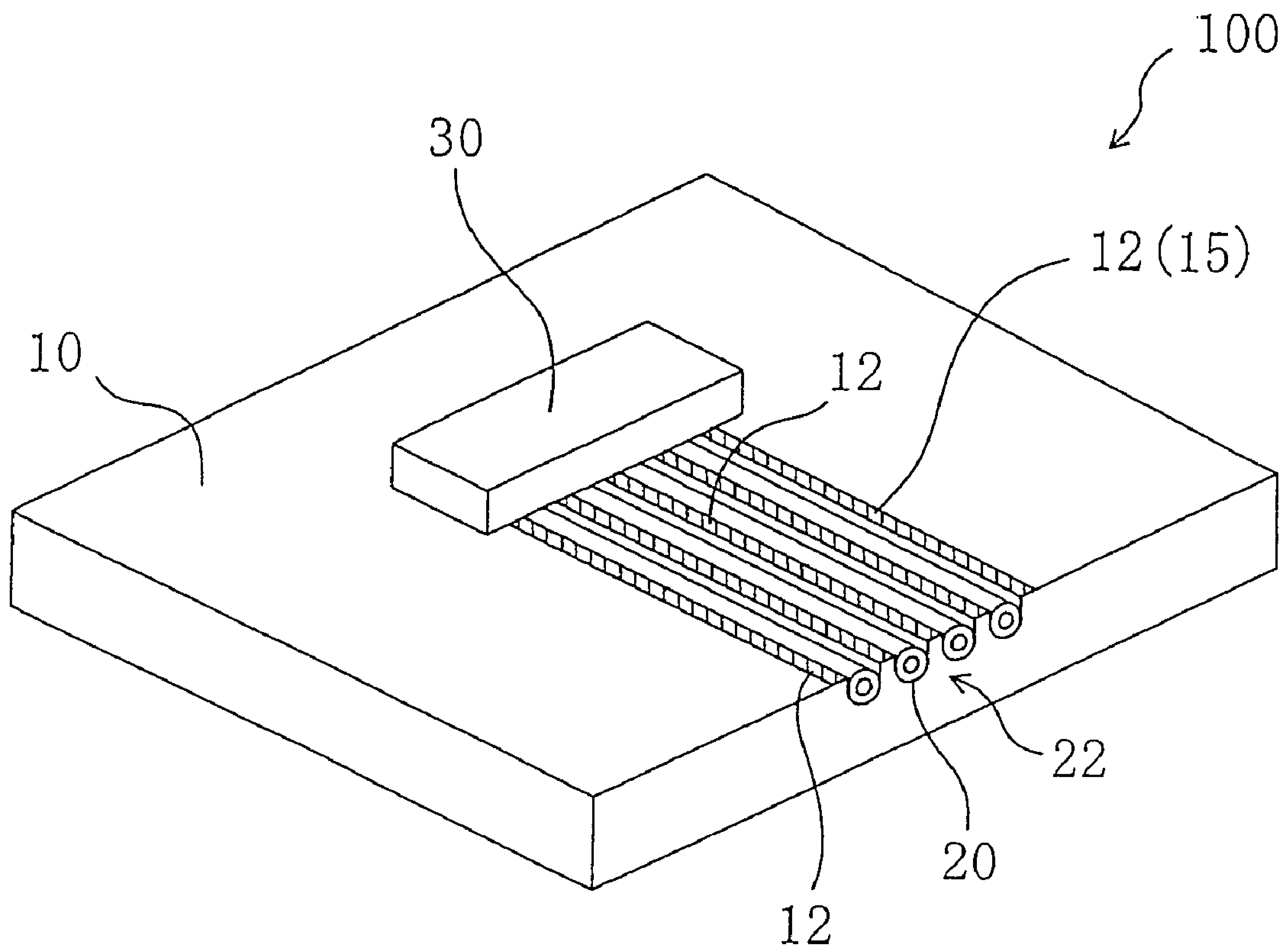


Fig.1



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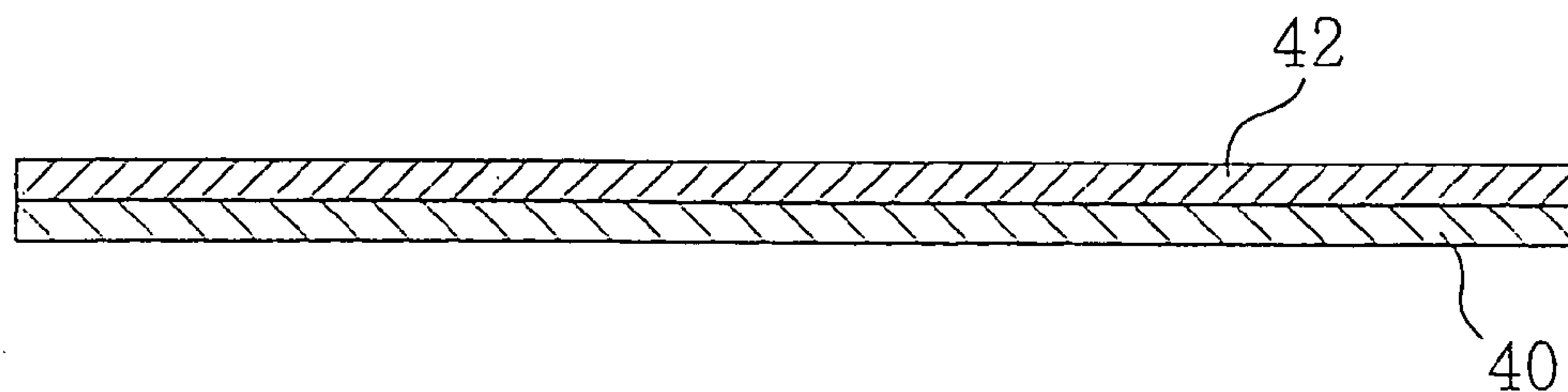

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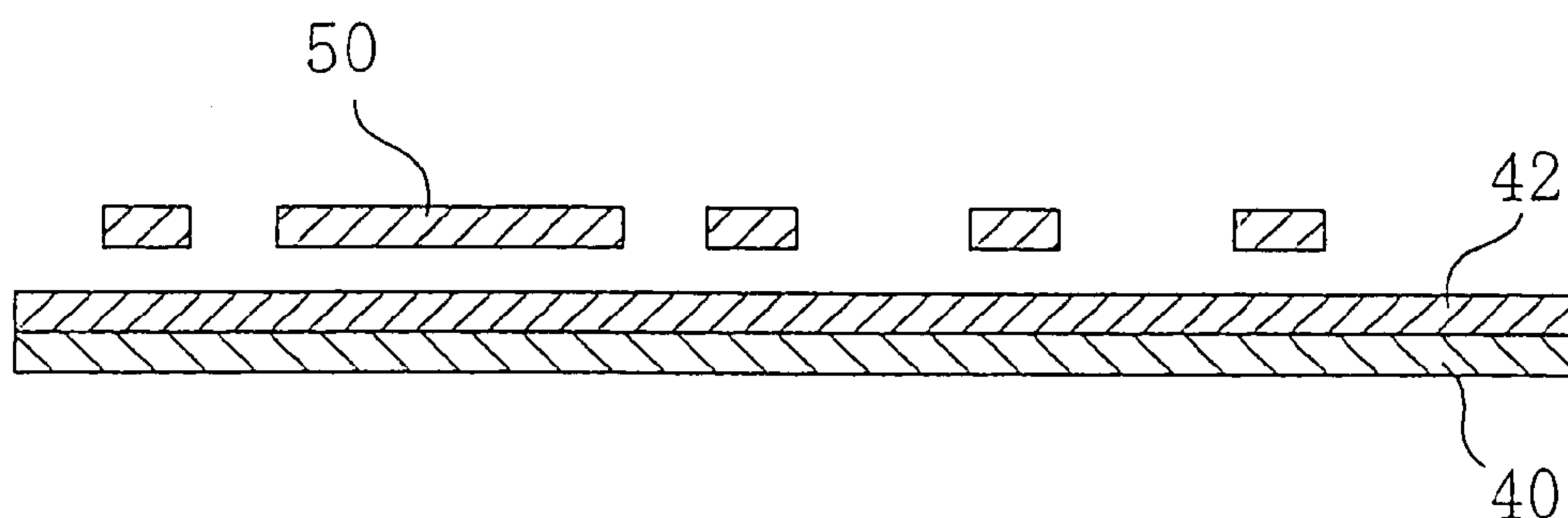

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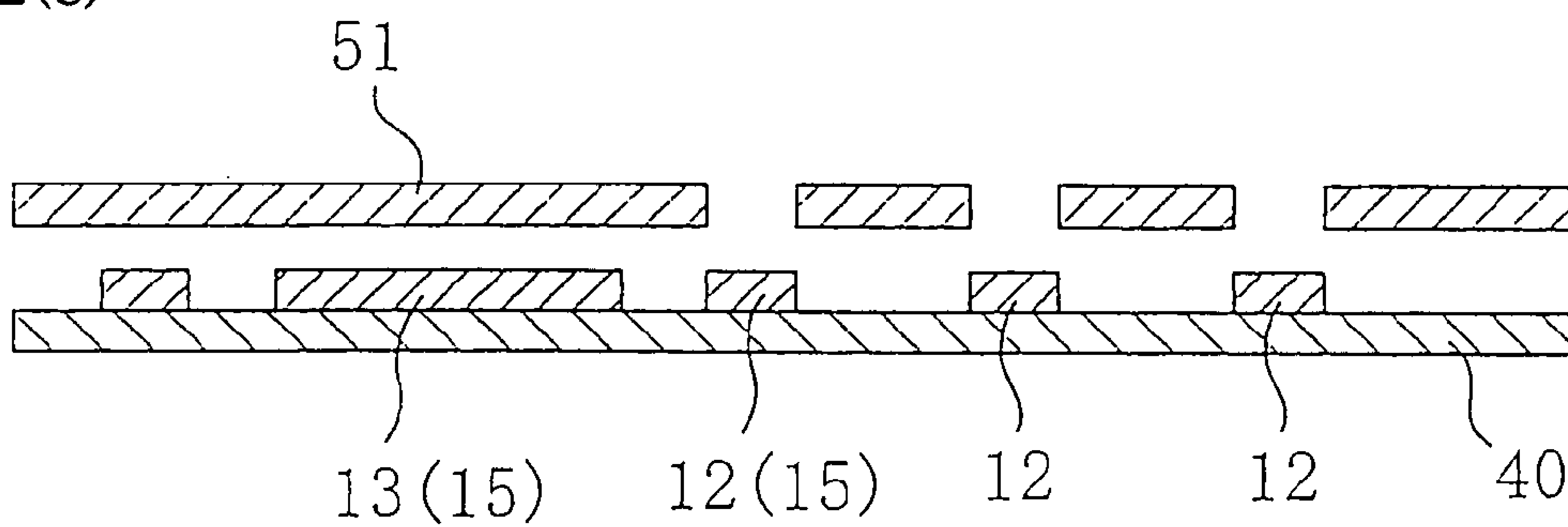

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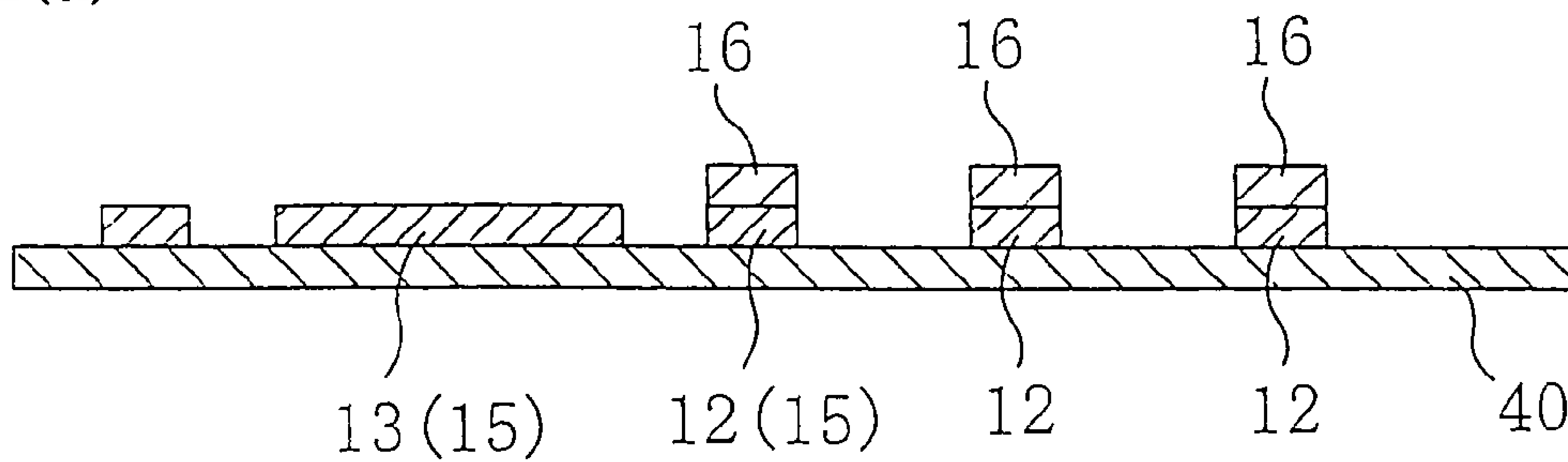

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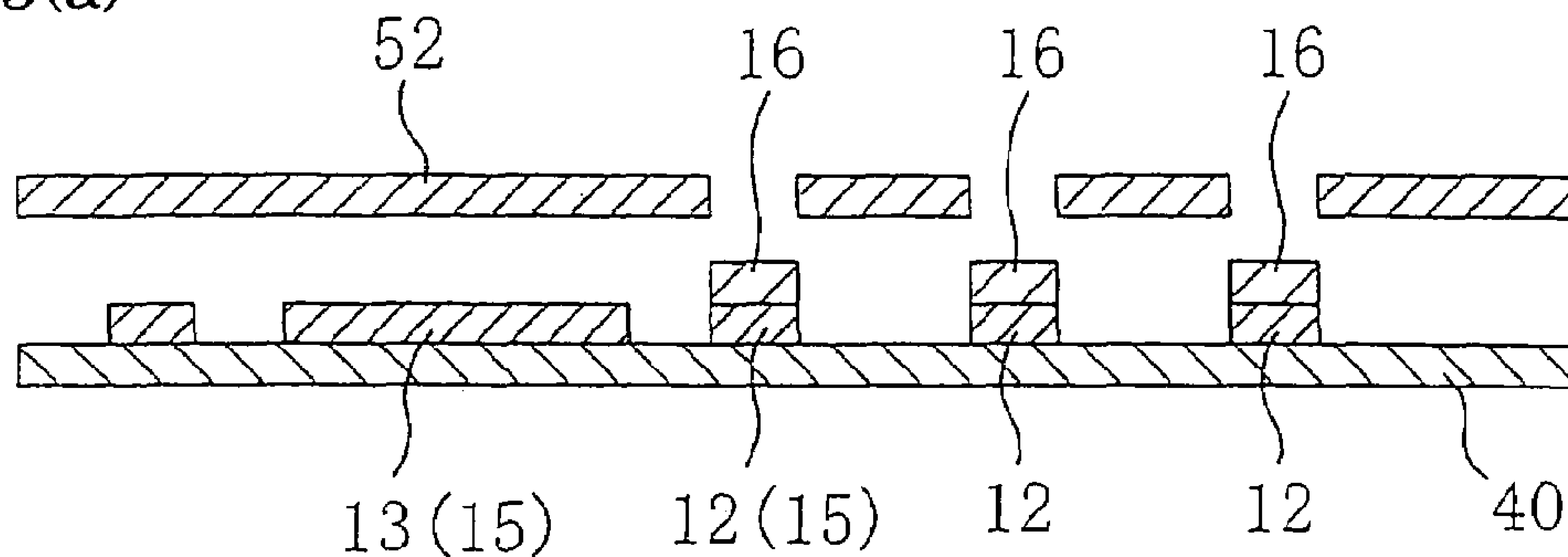

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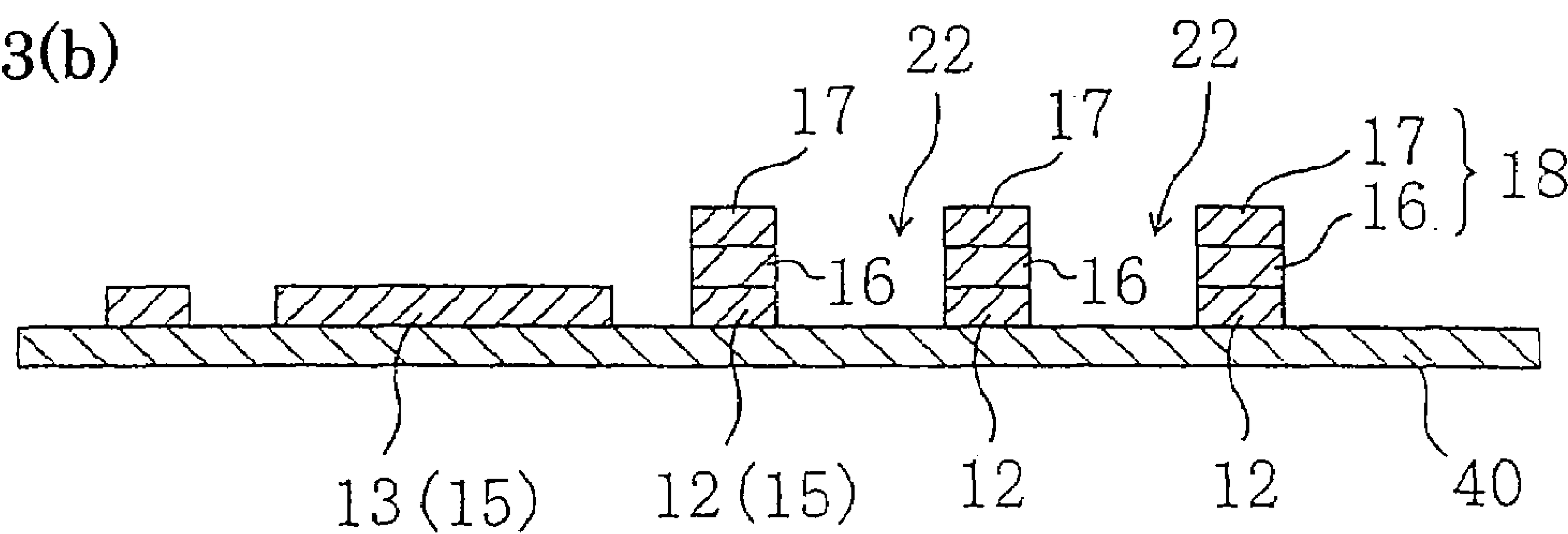

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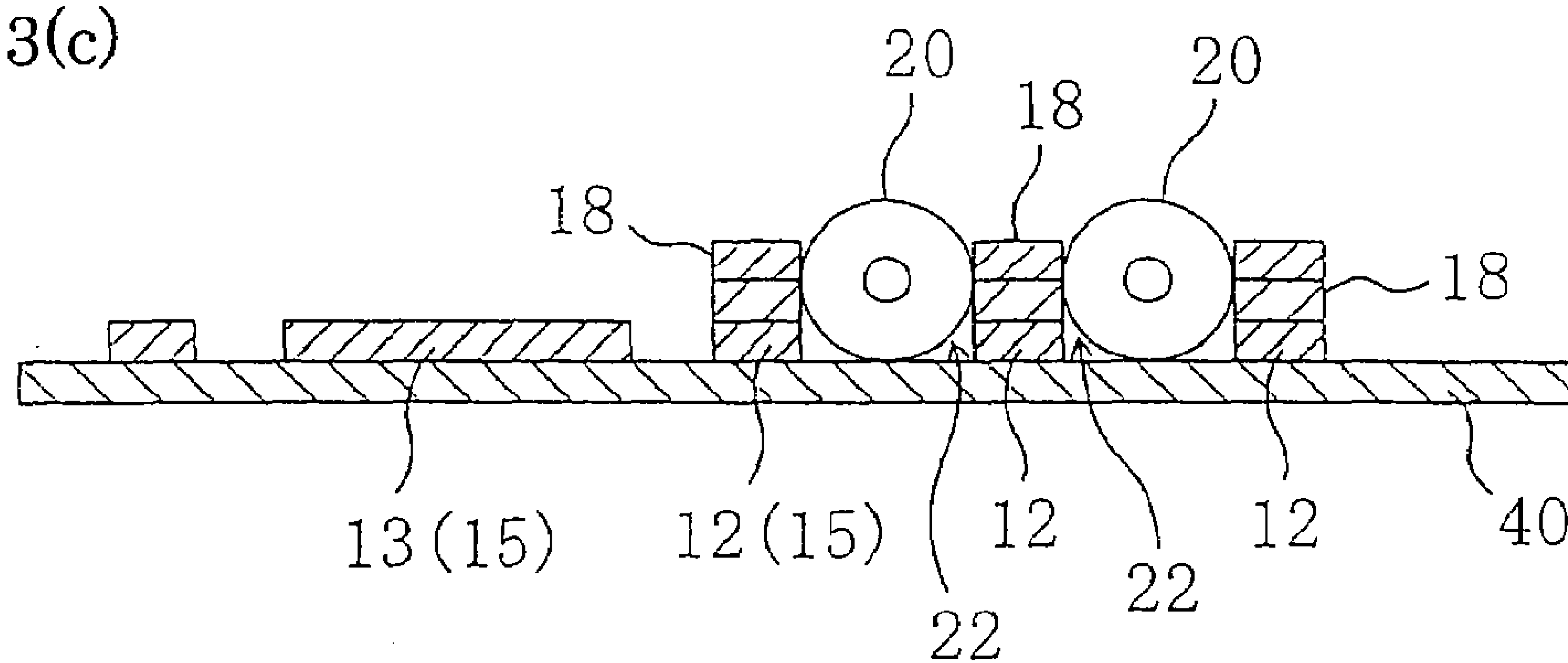

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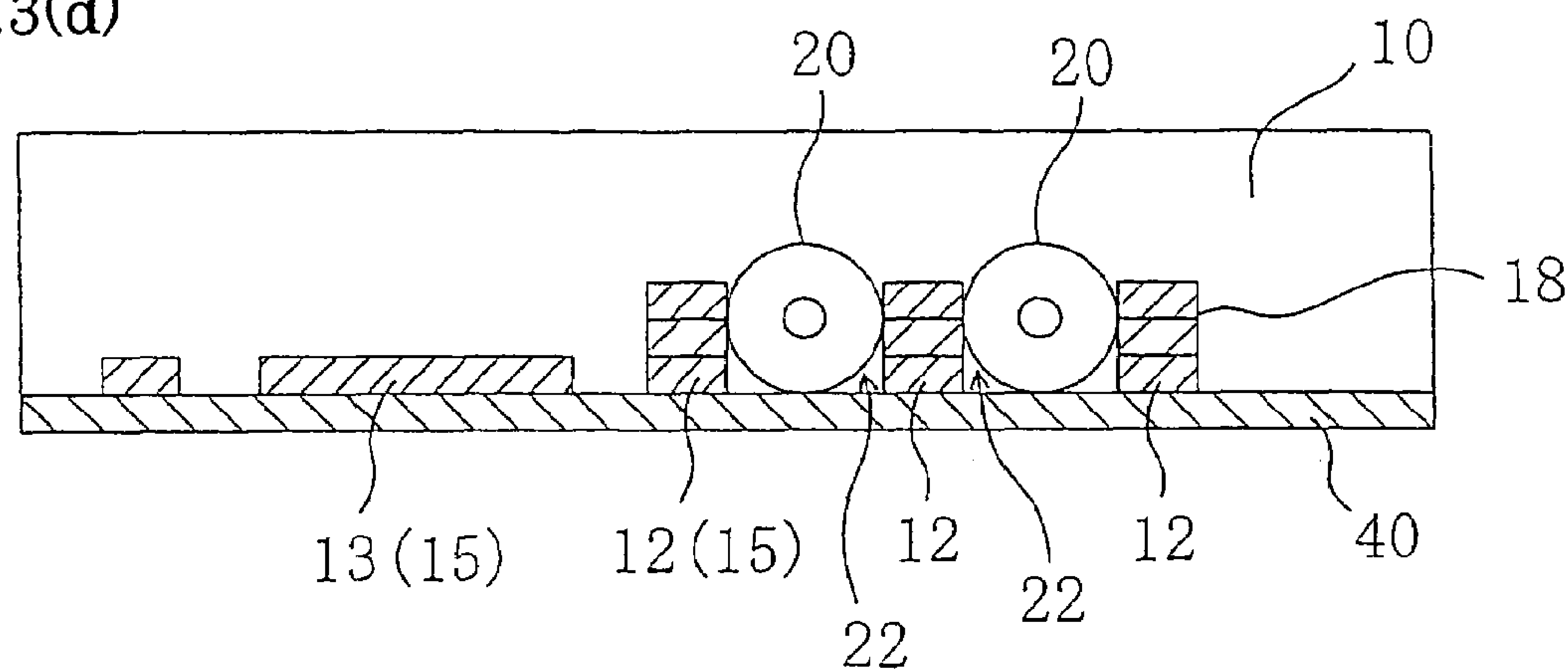

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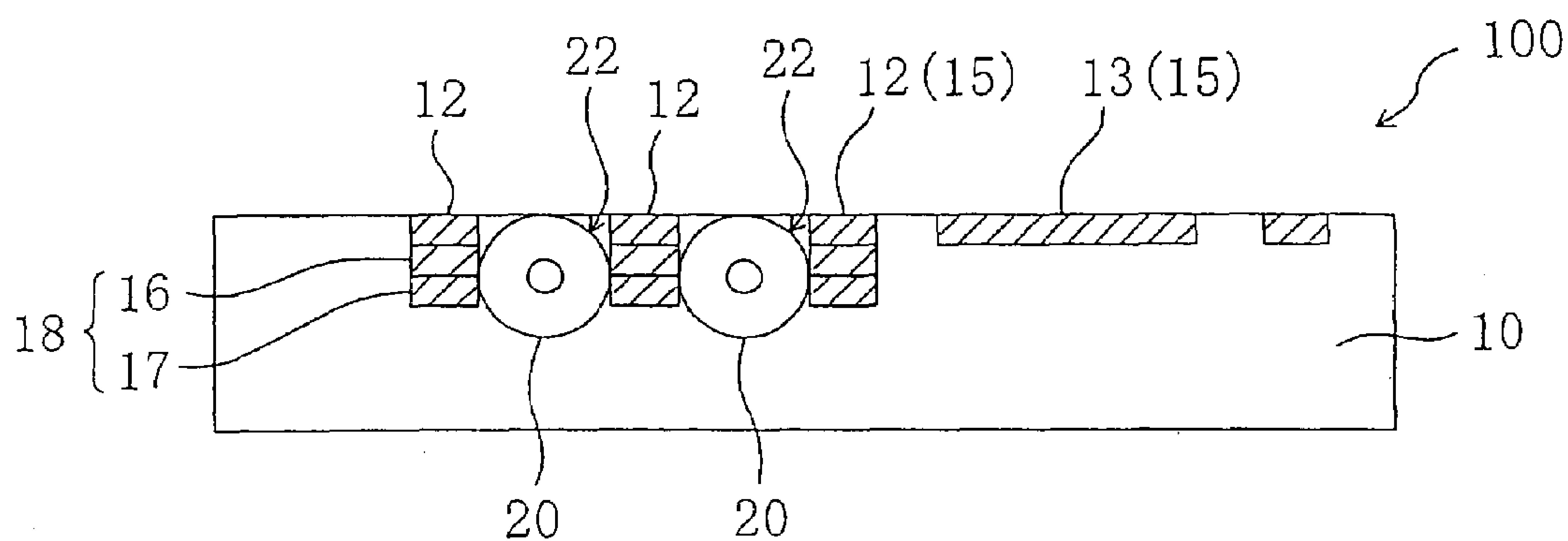

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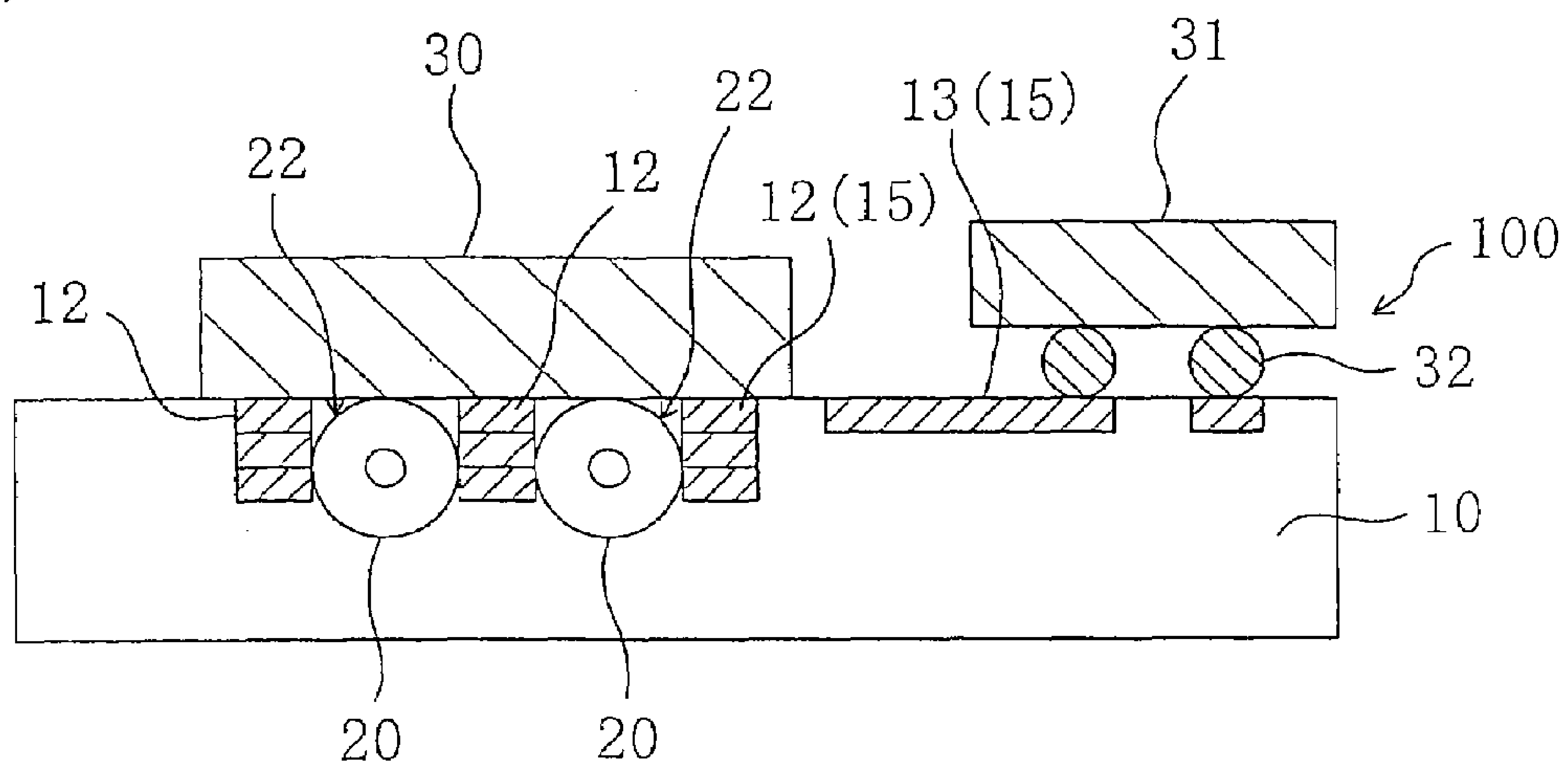

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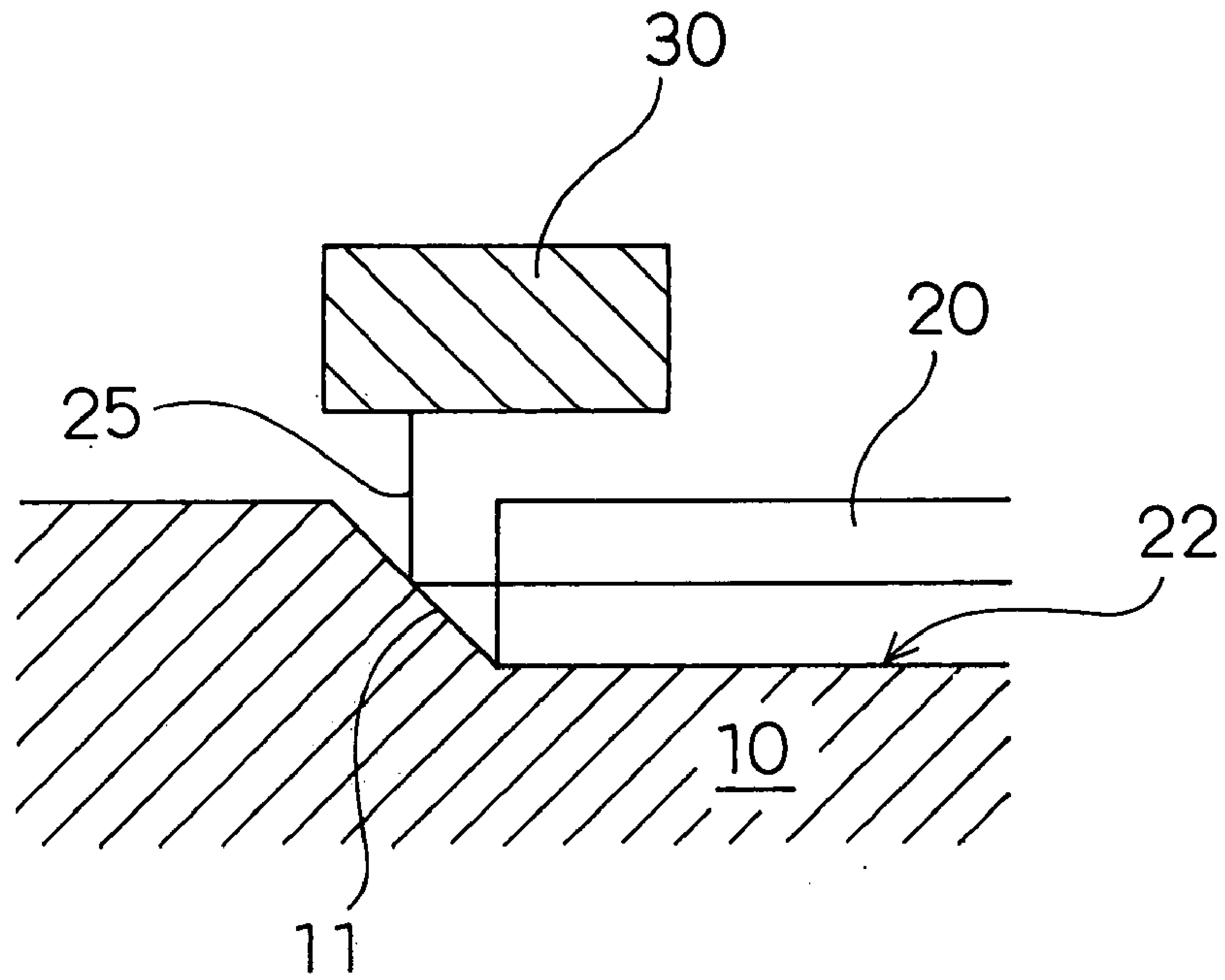

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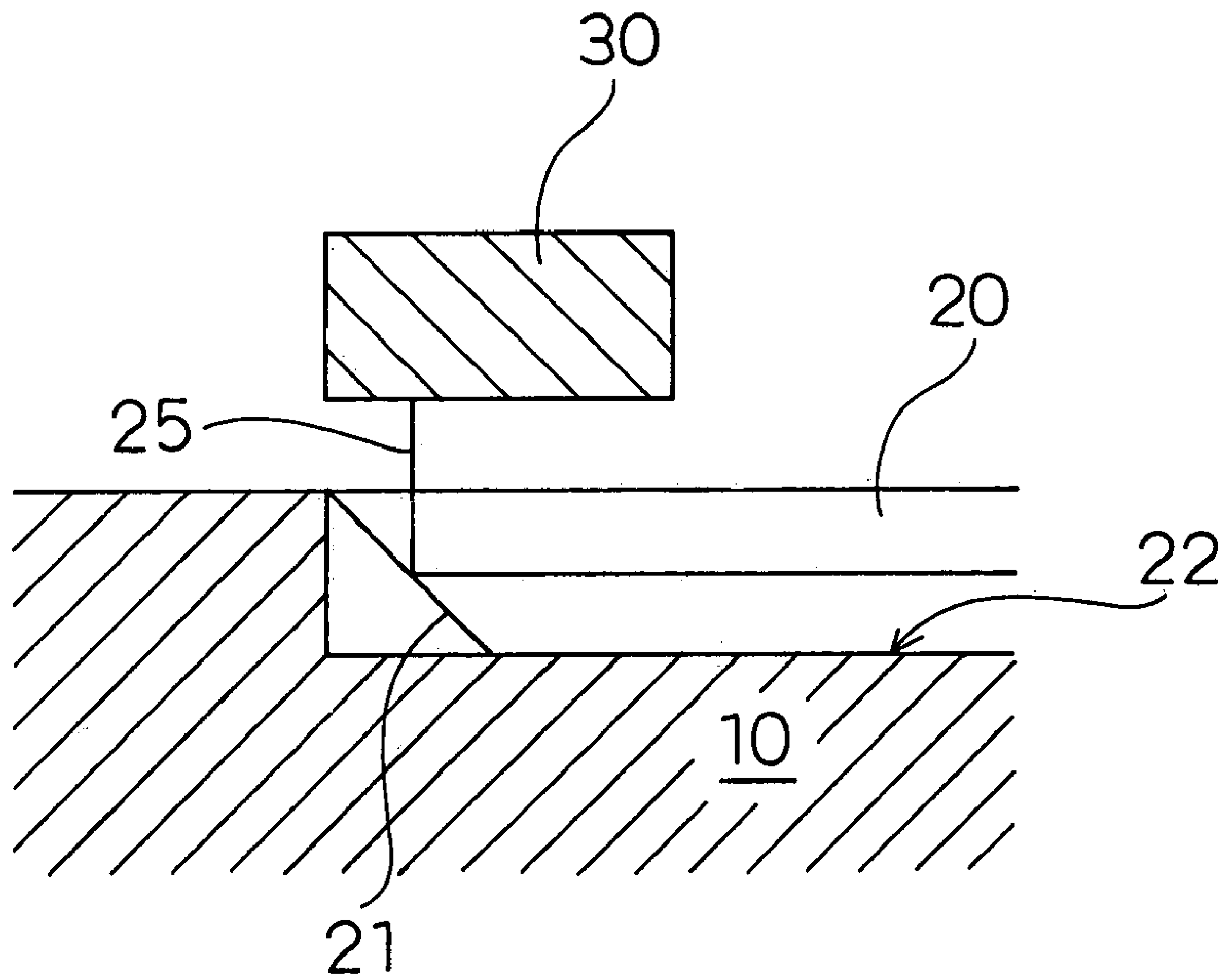

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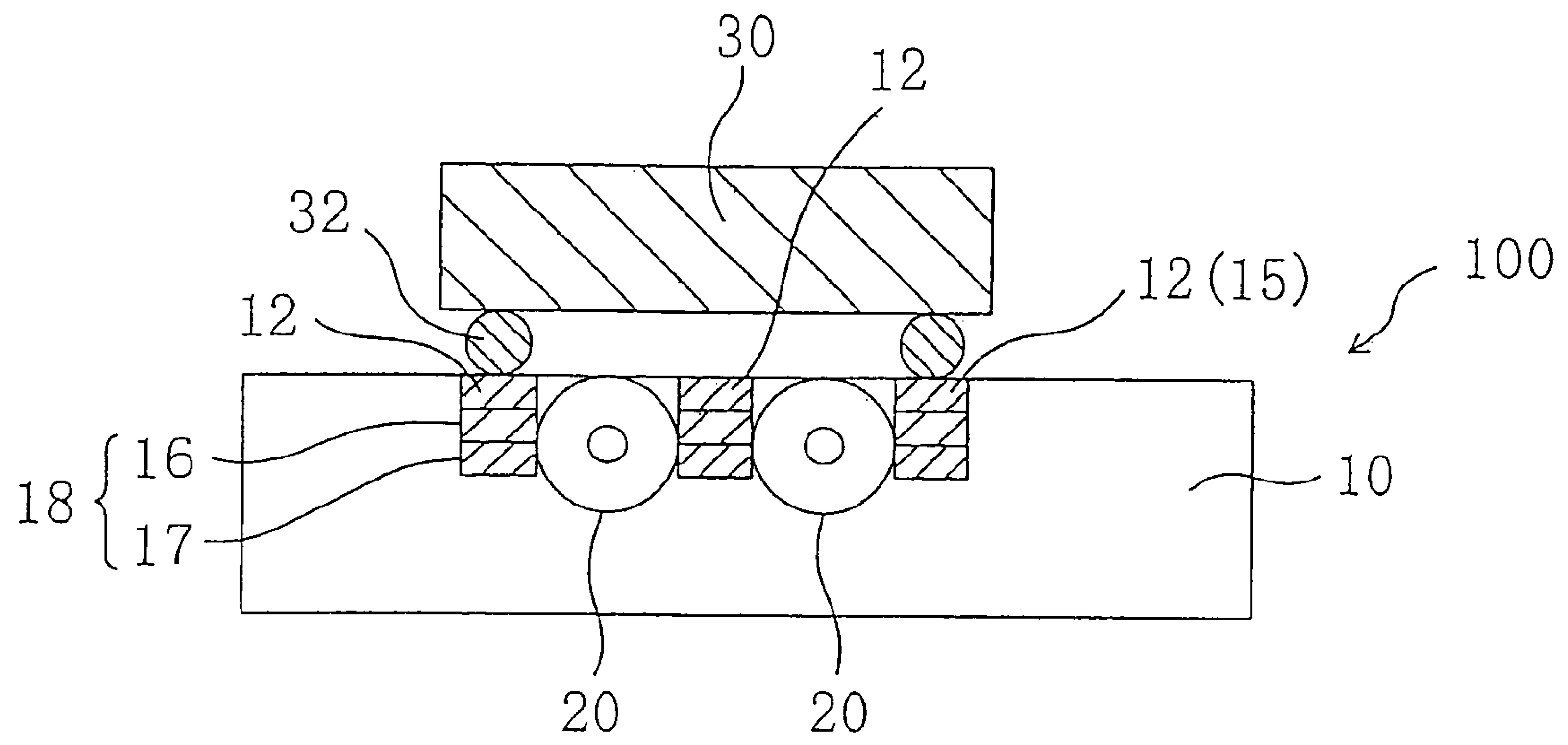

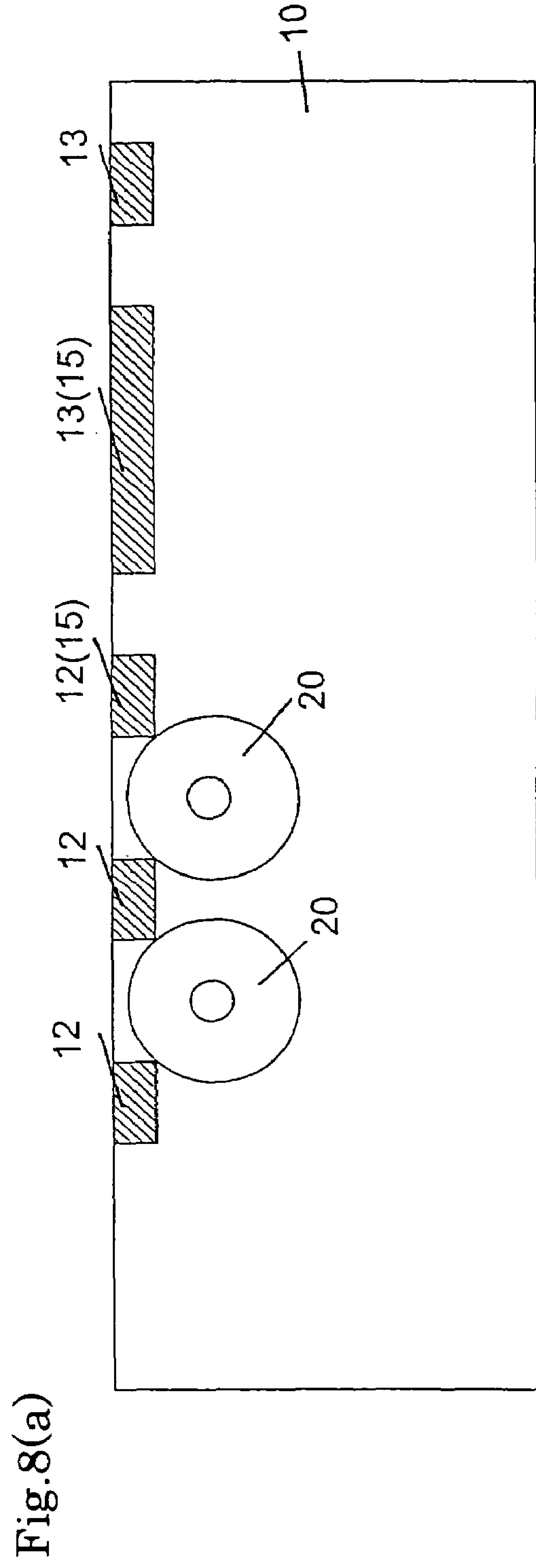

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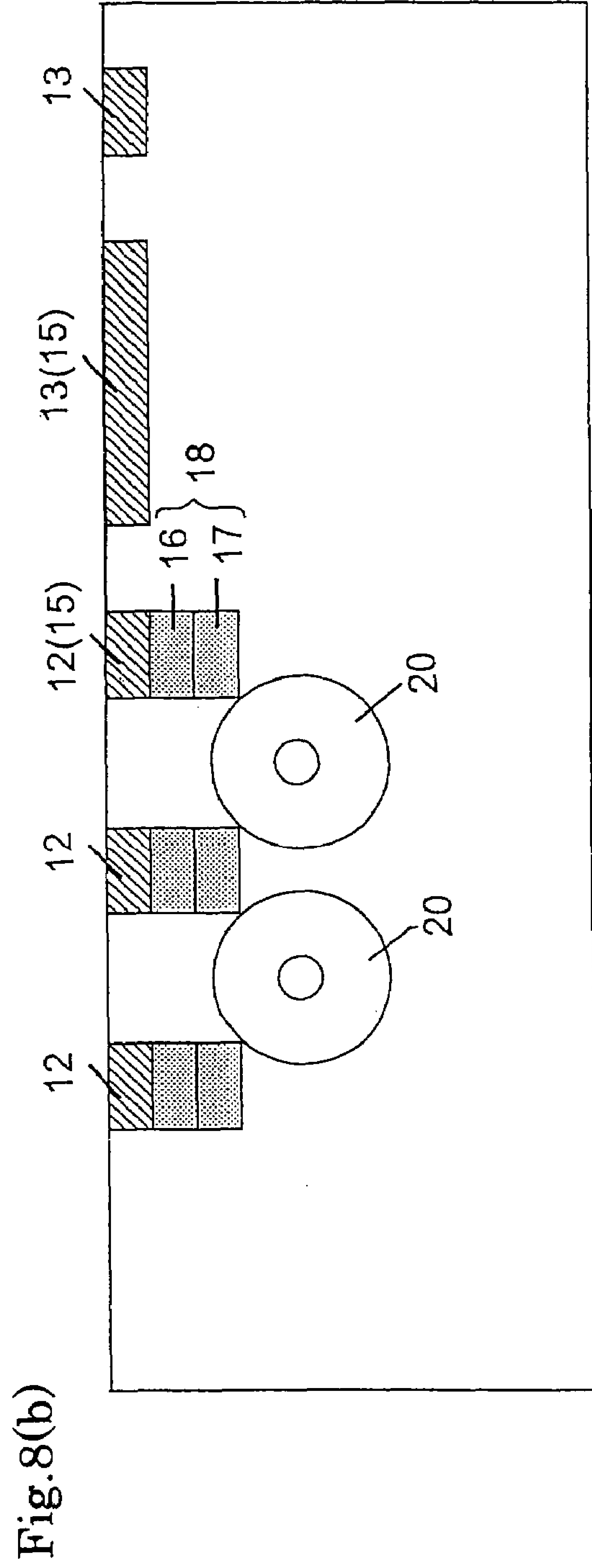

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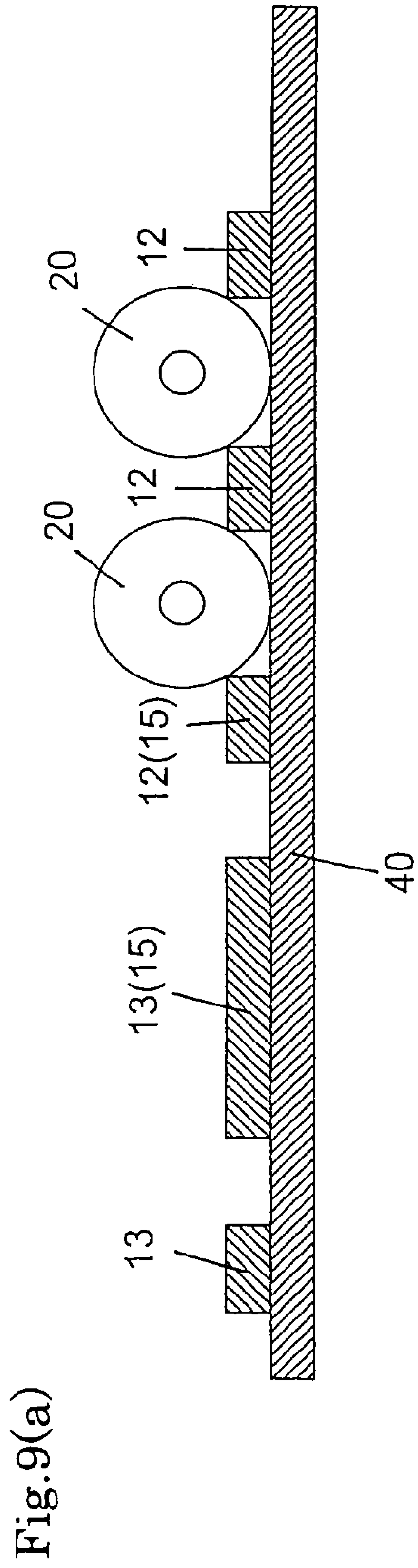

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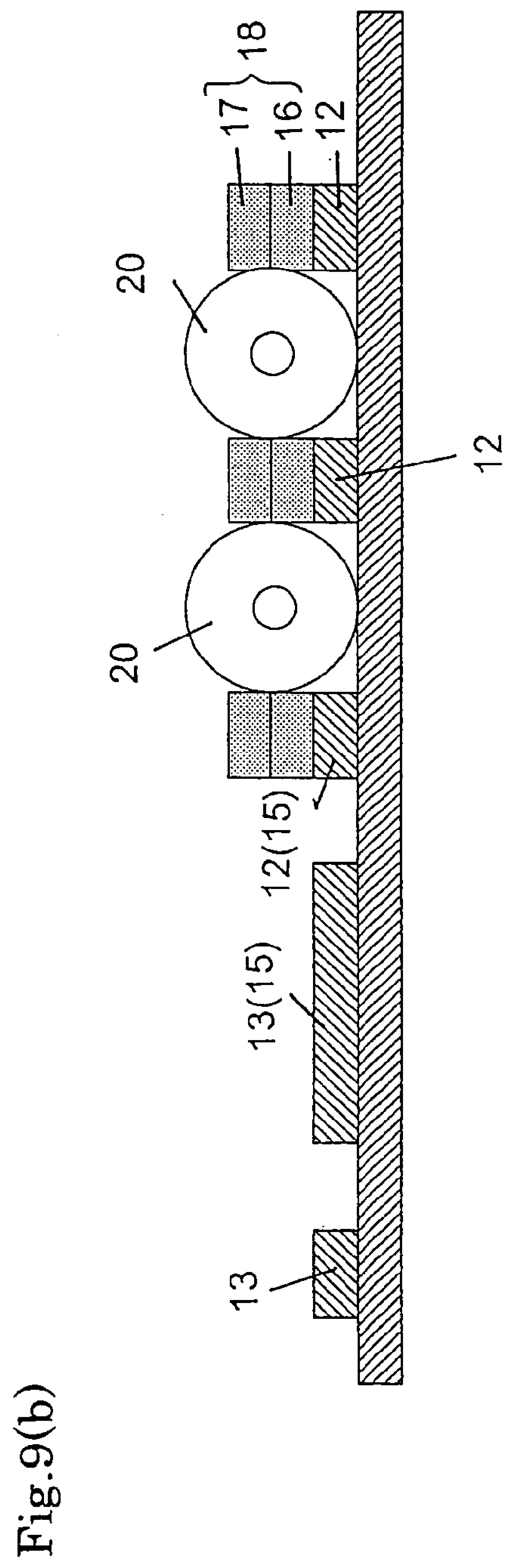

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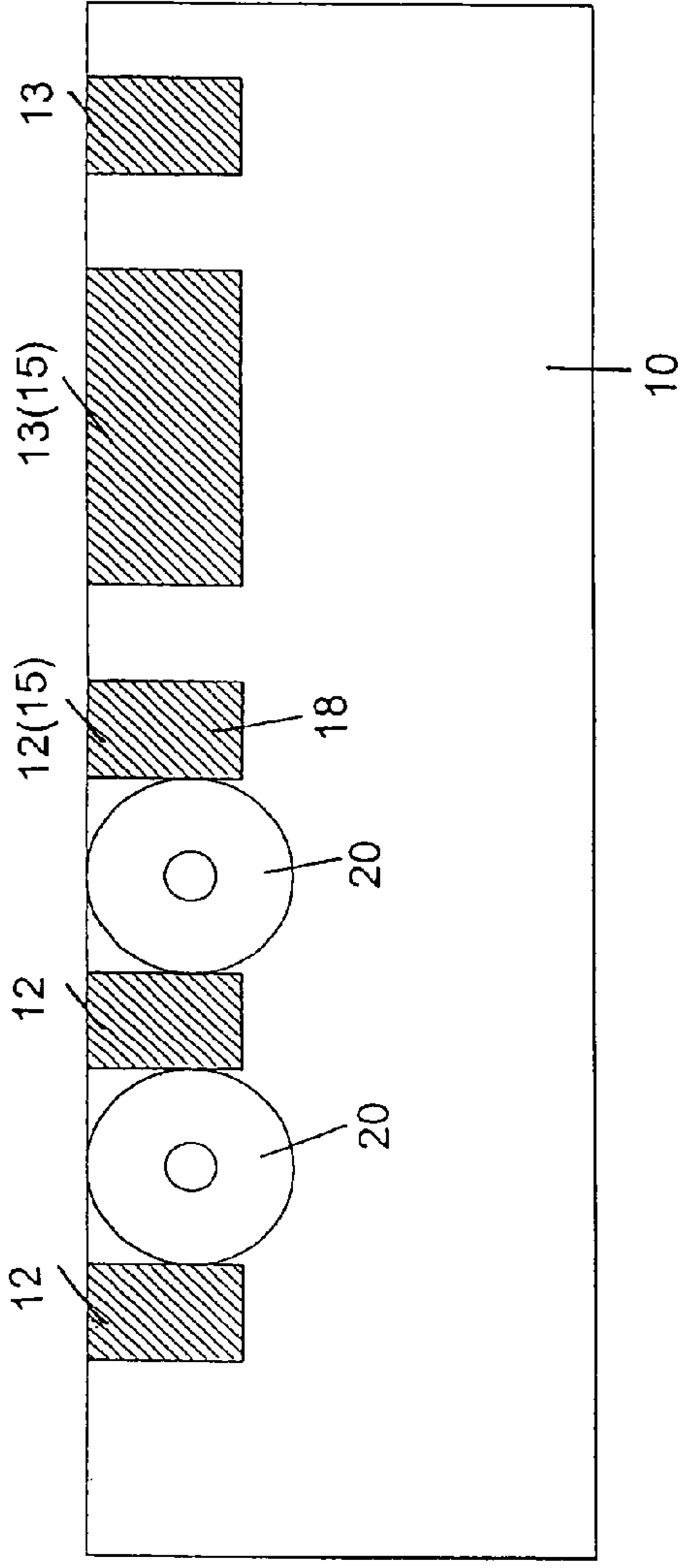

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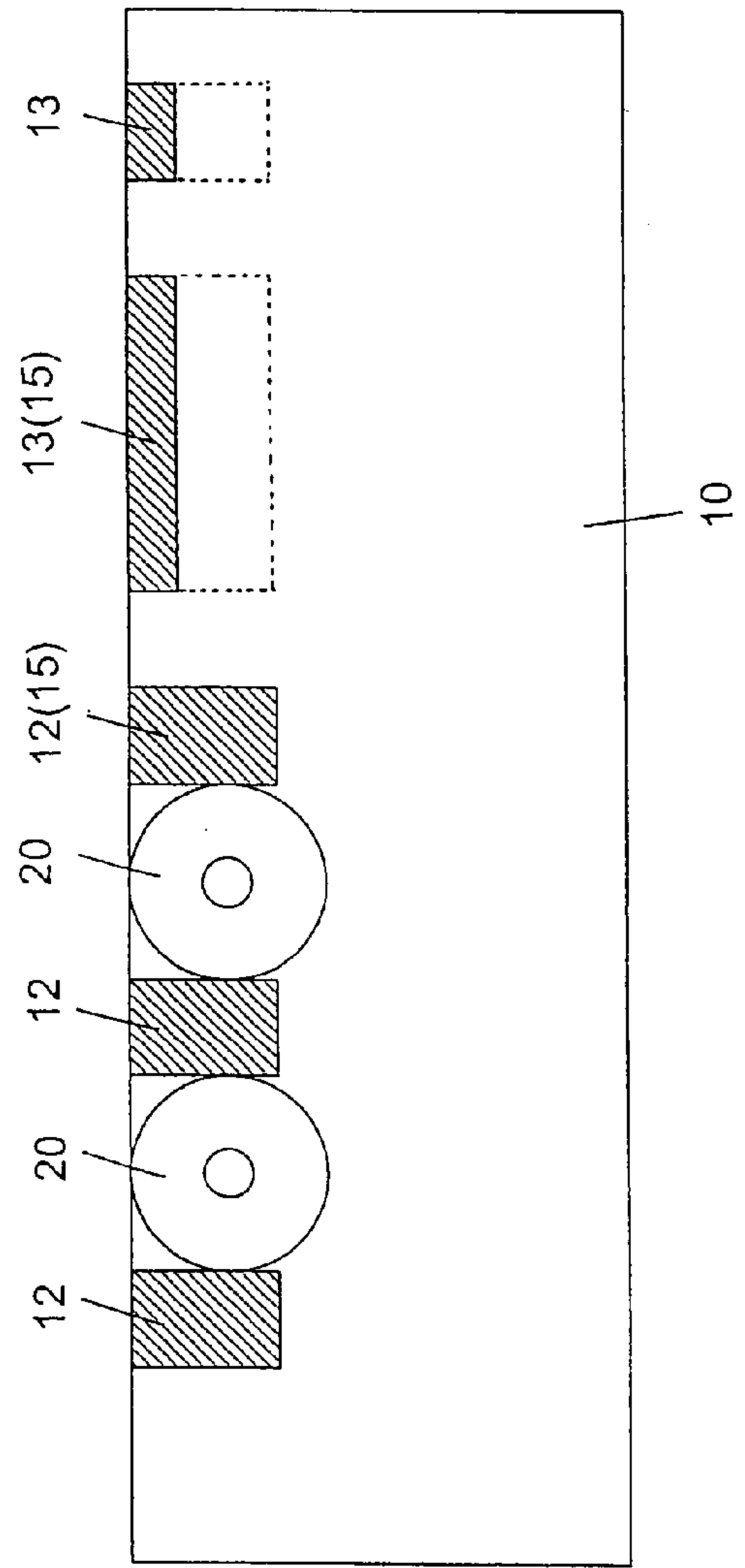
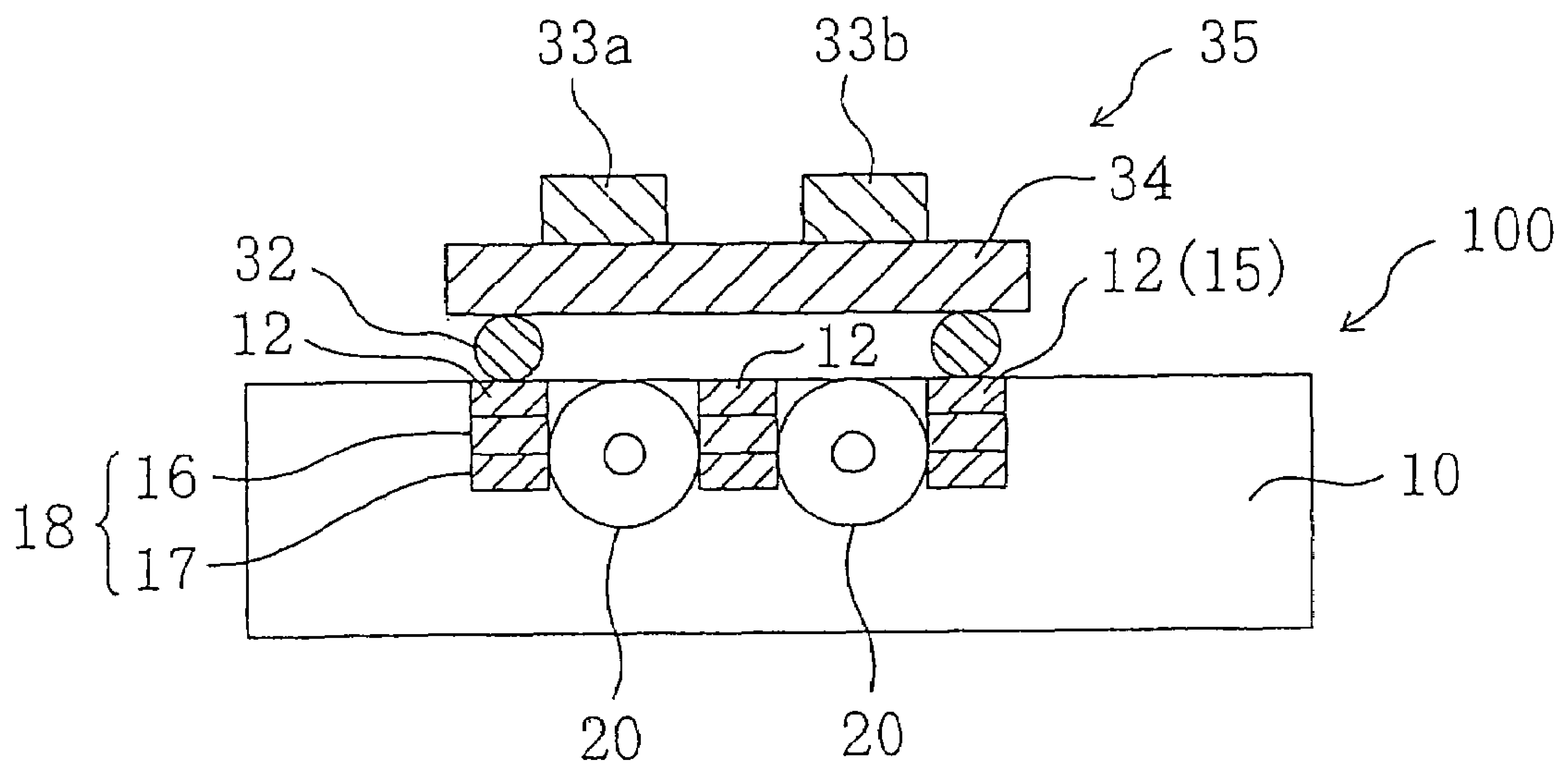


Fig.10(b)

Fig.11



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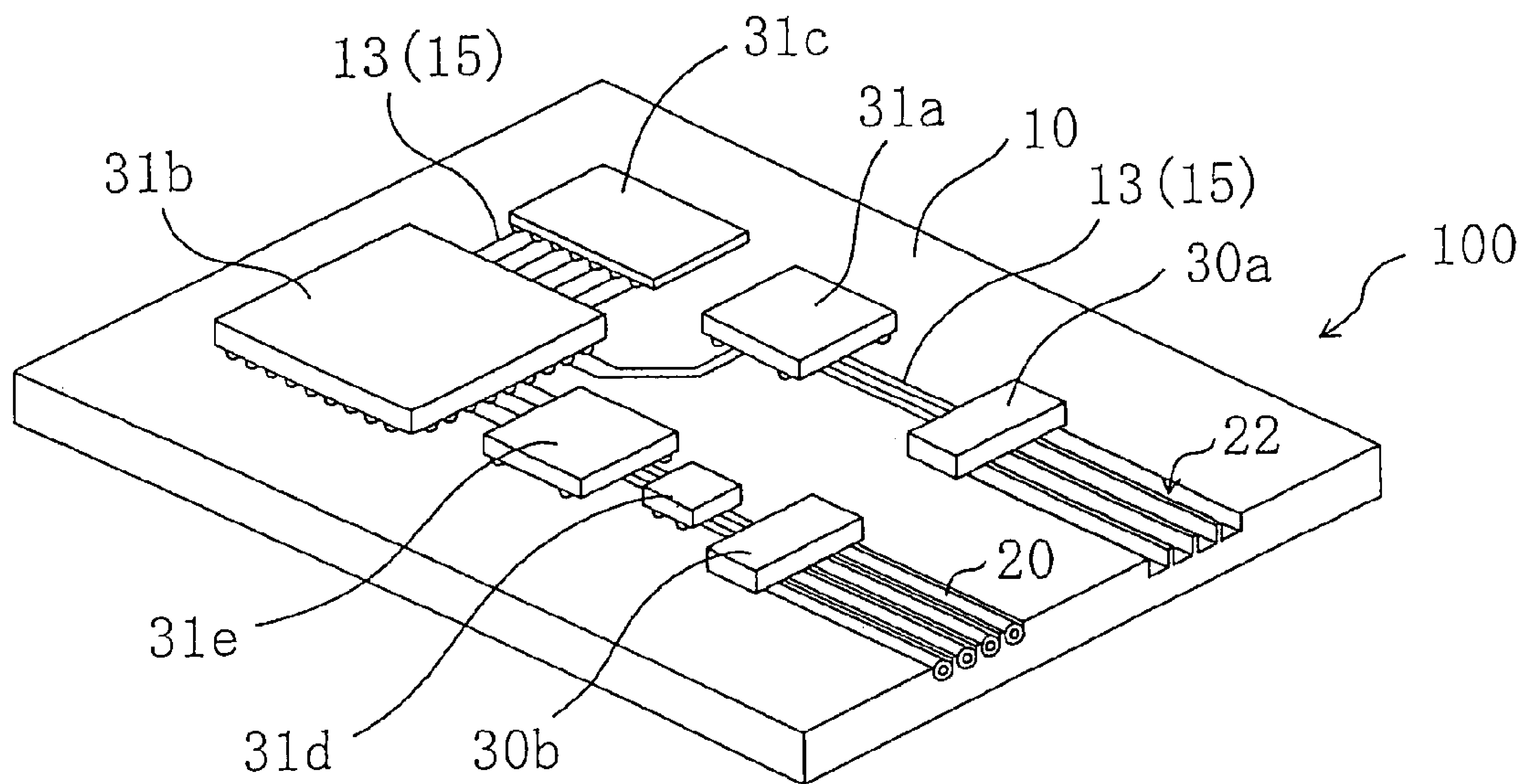

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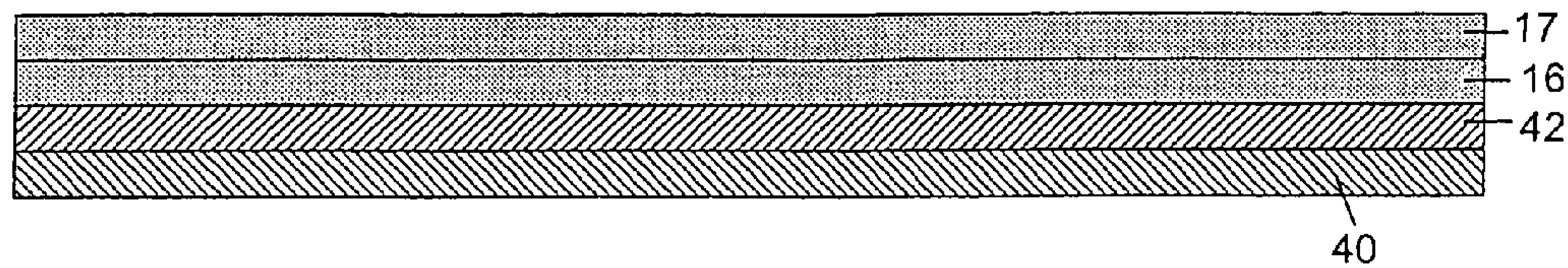

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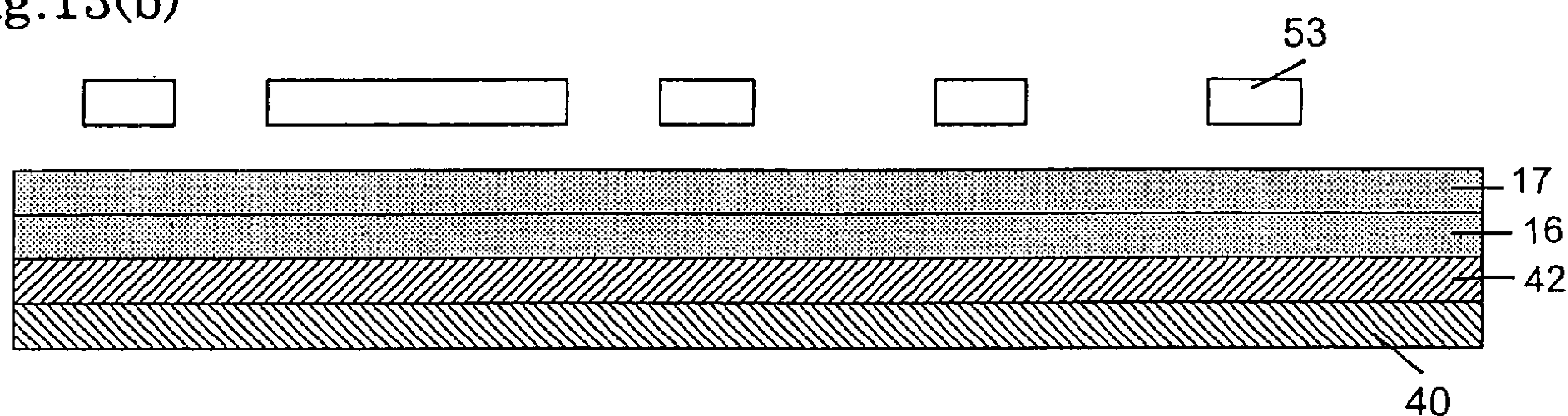

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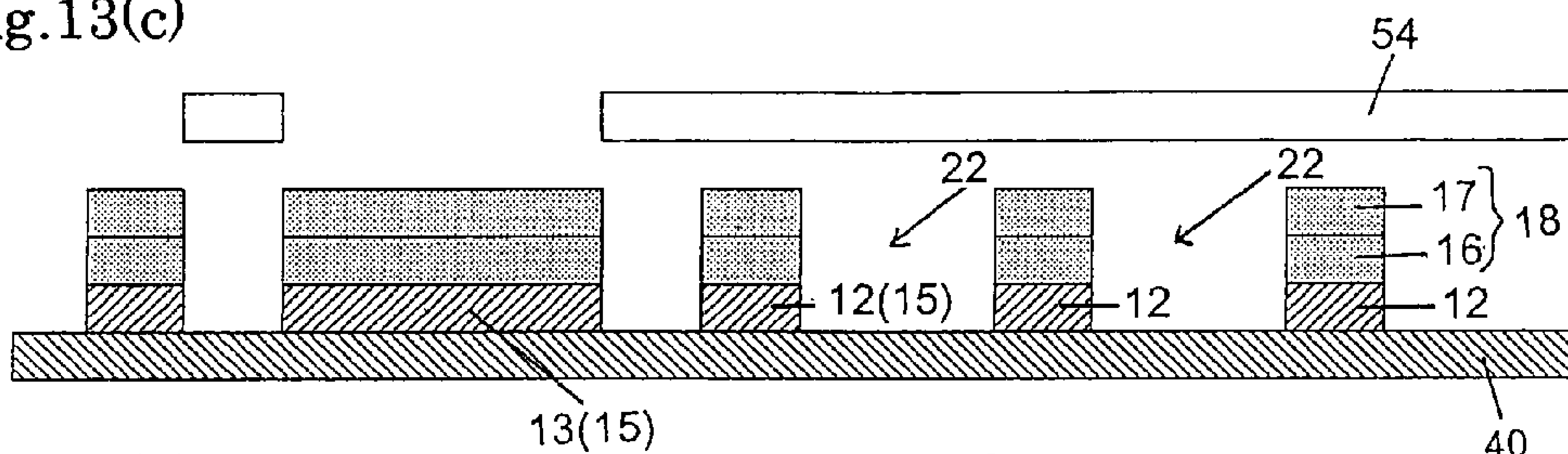

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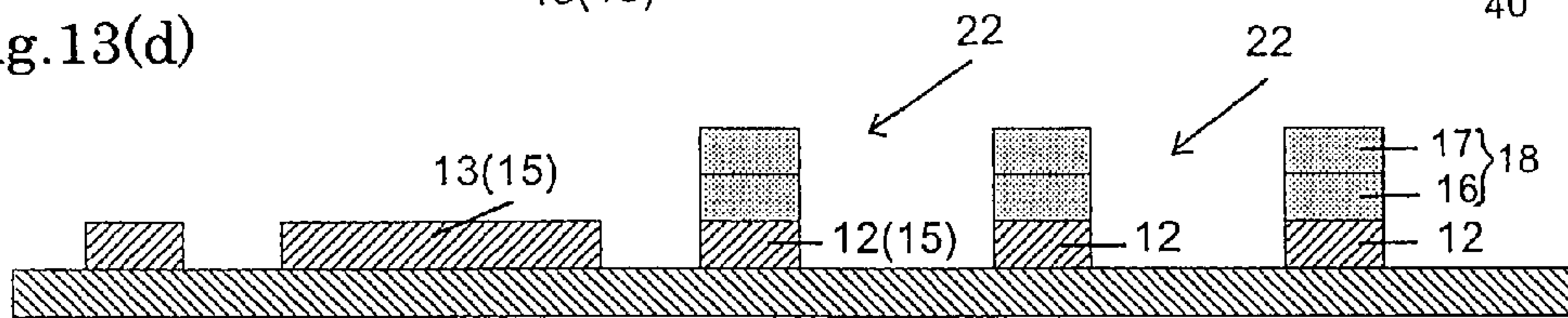

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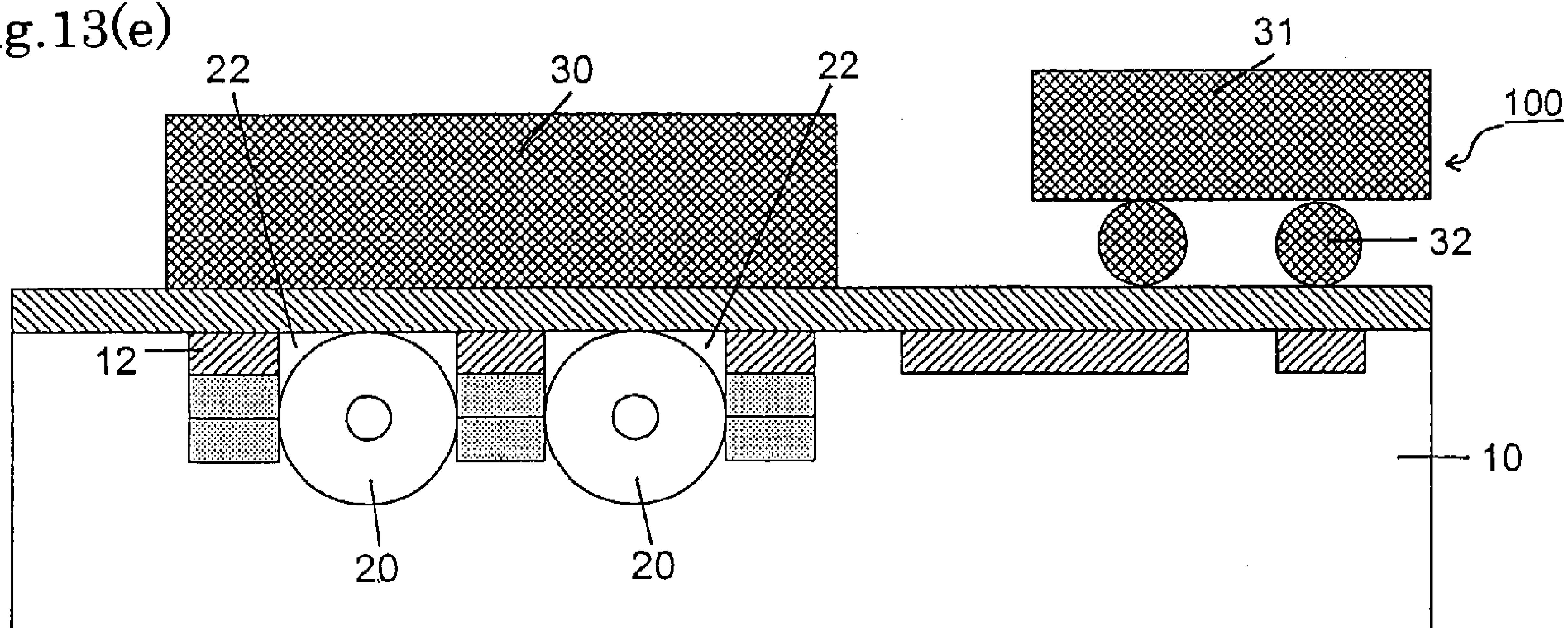

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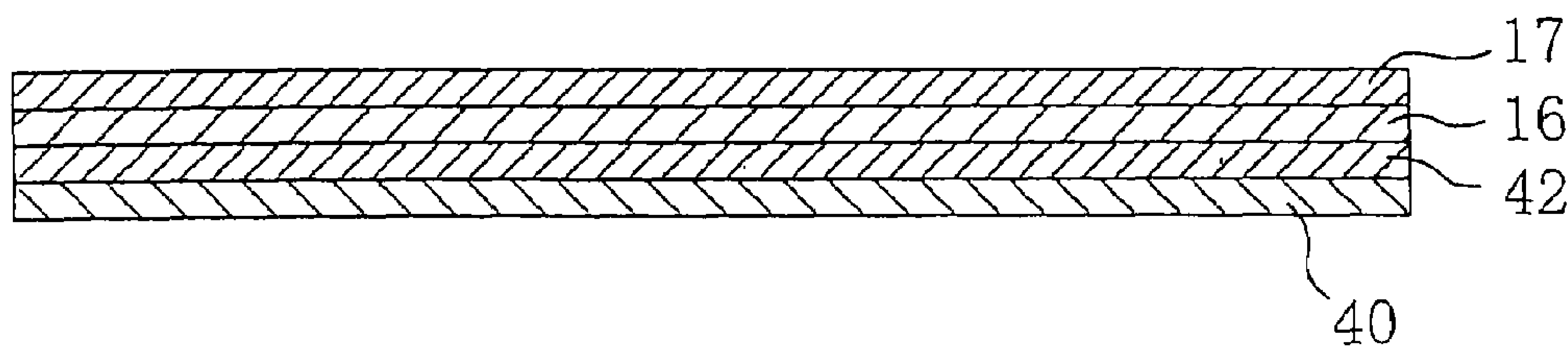

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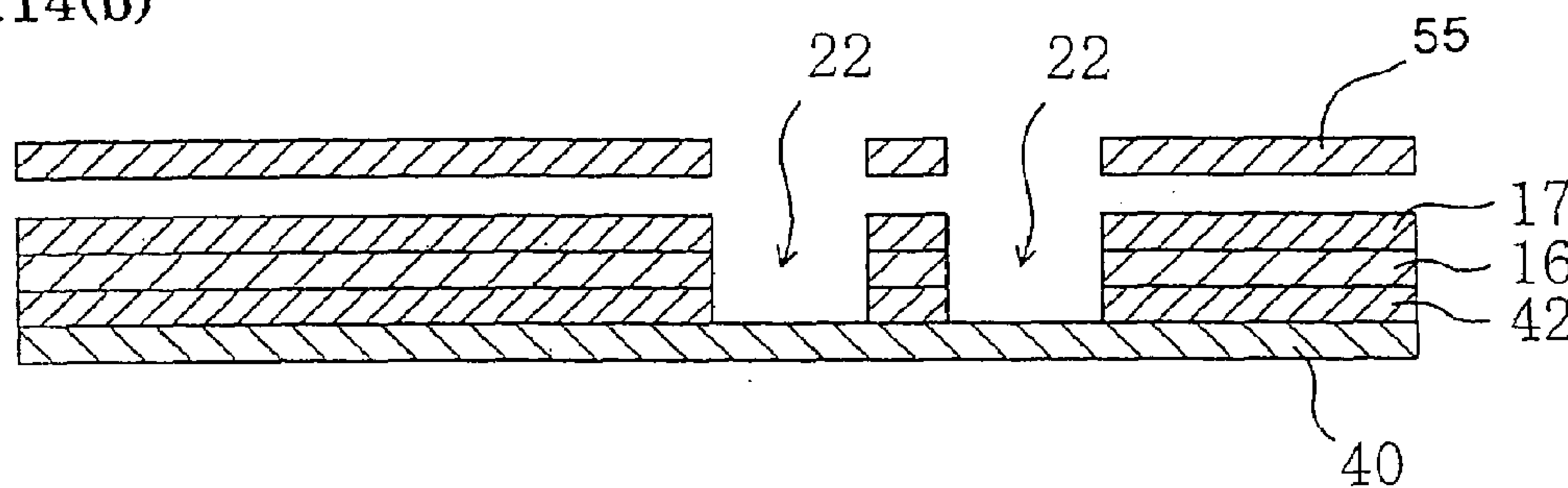

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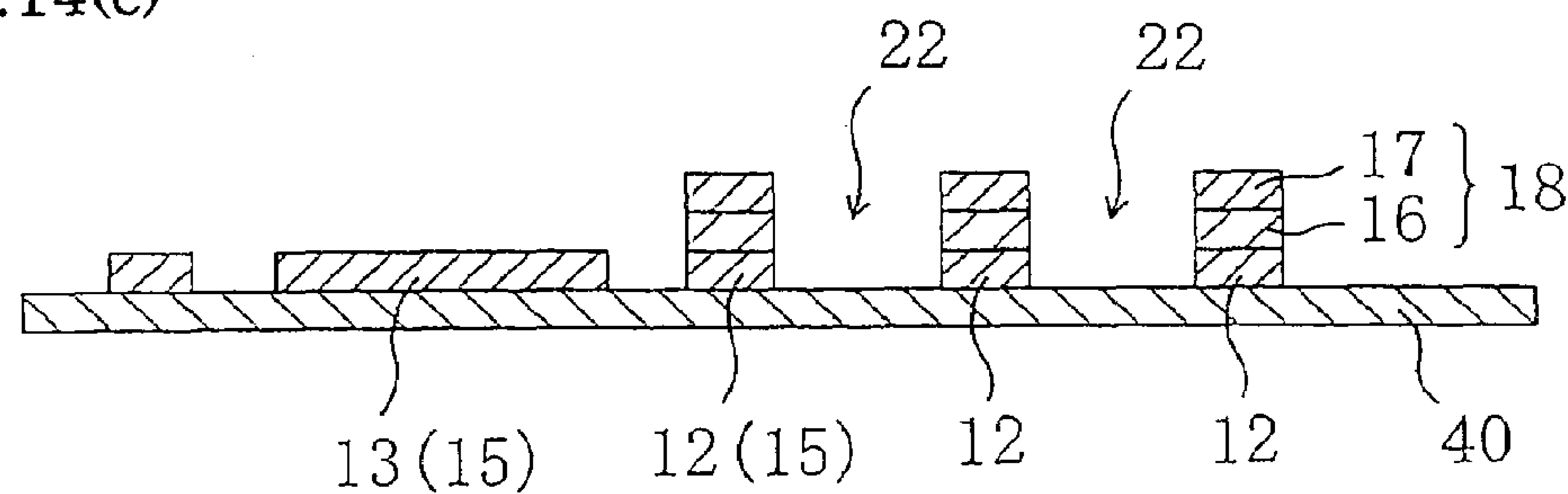

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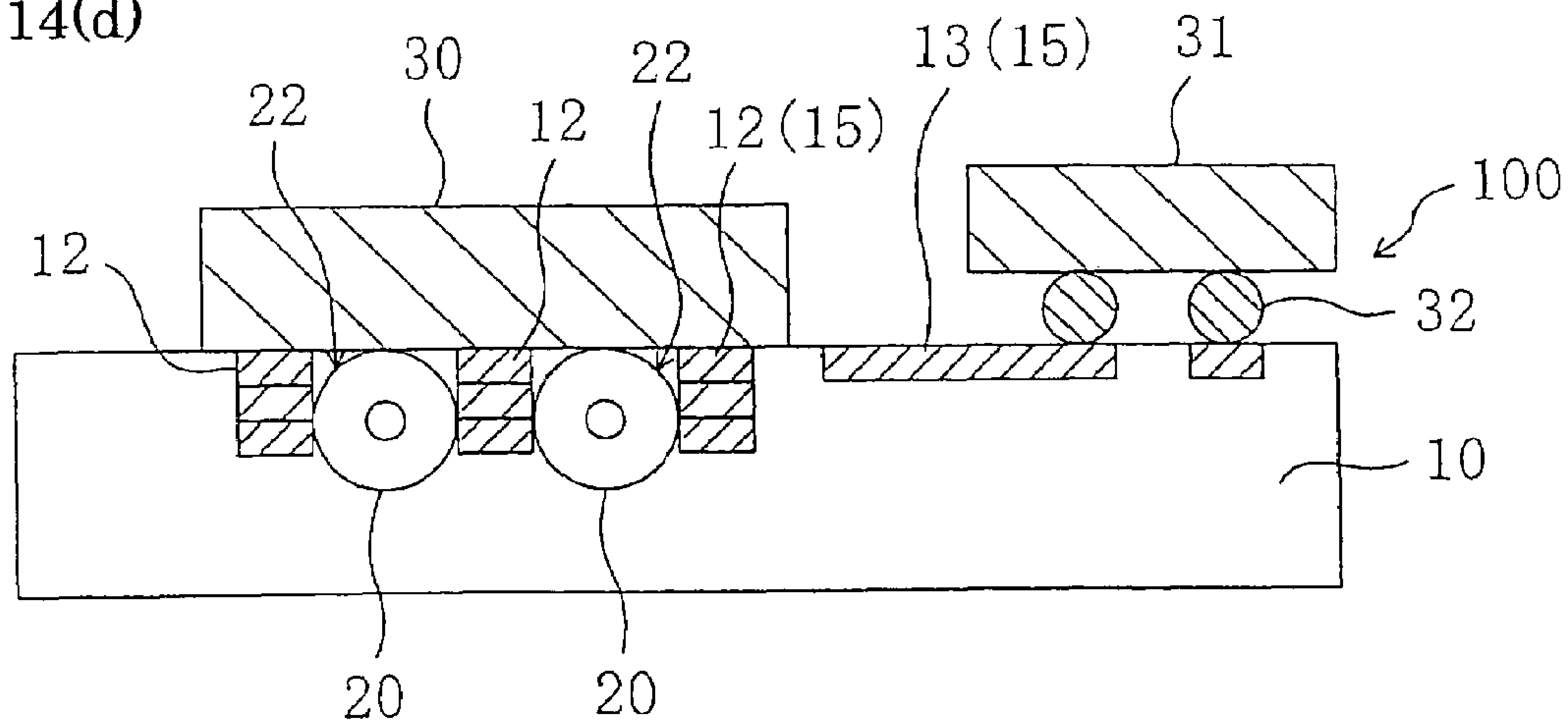

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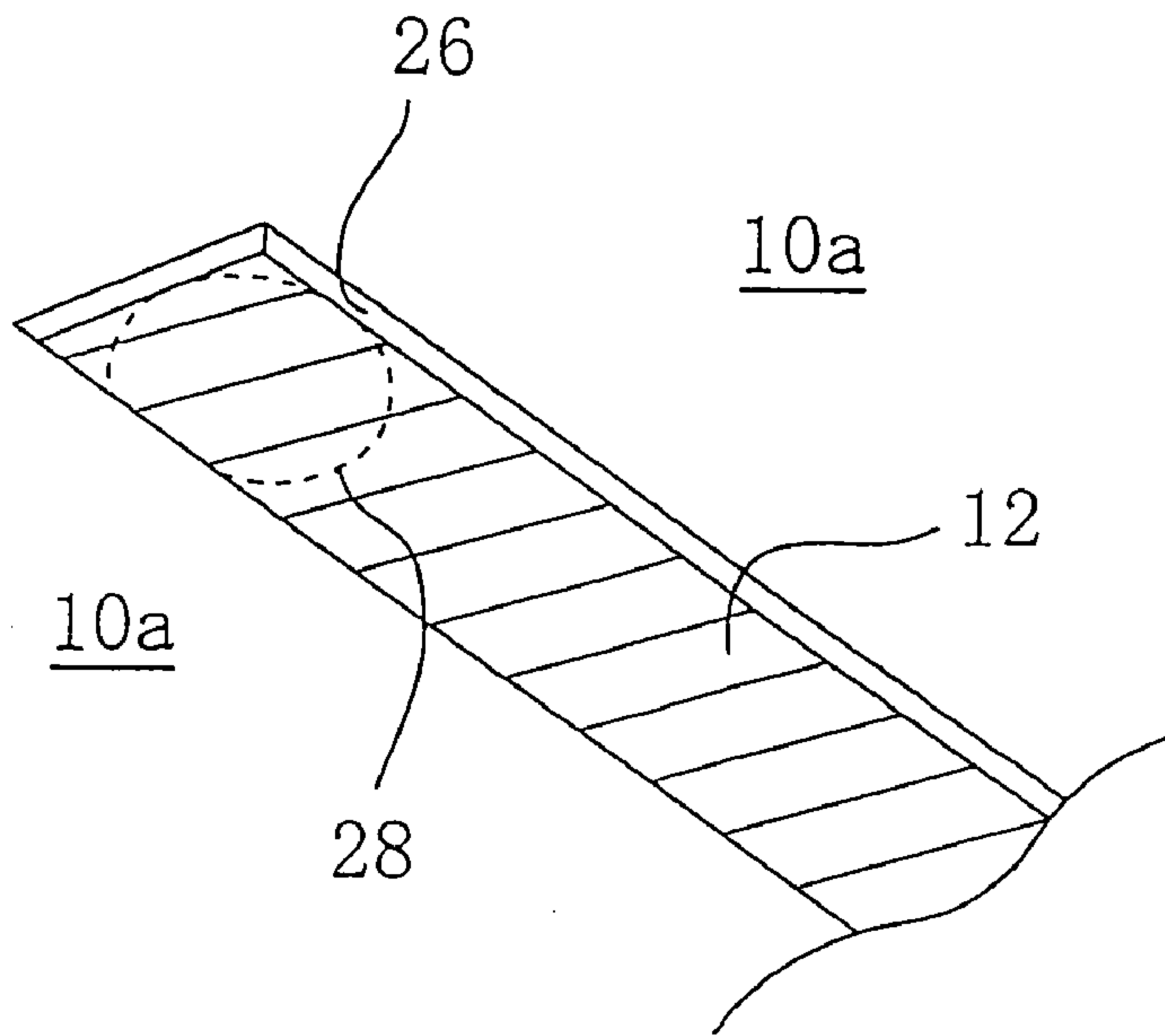

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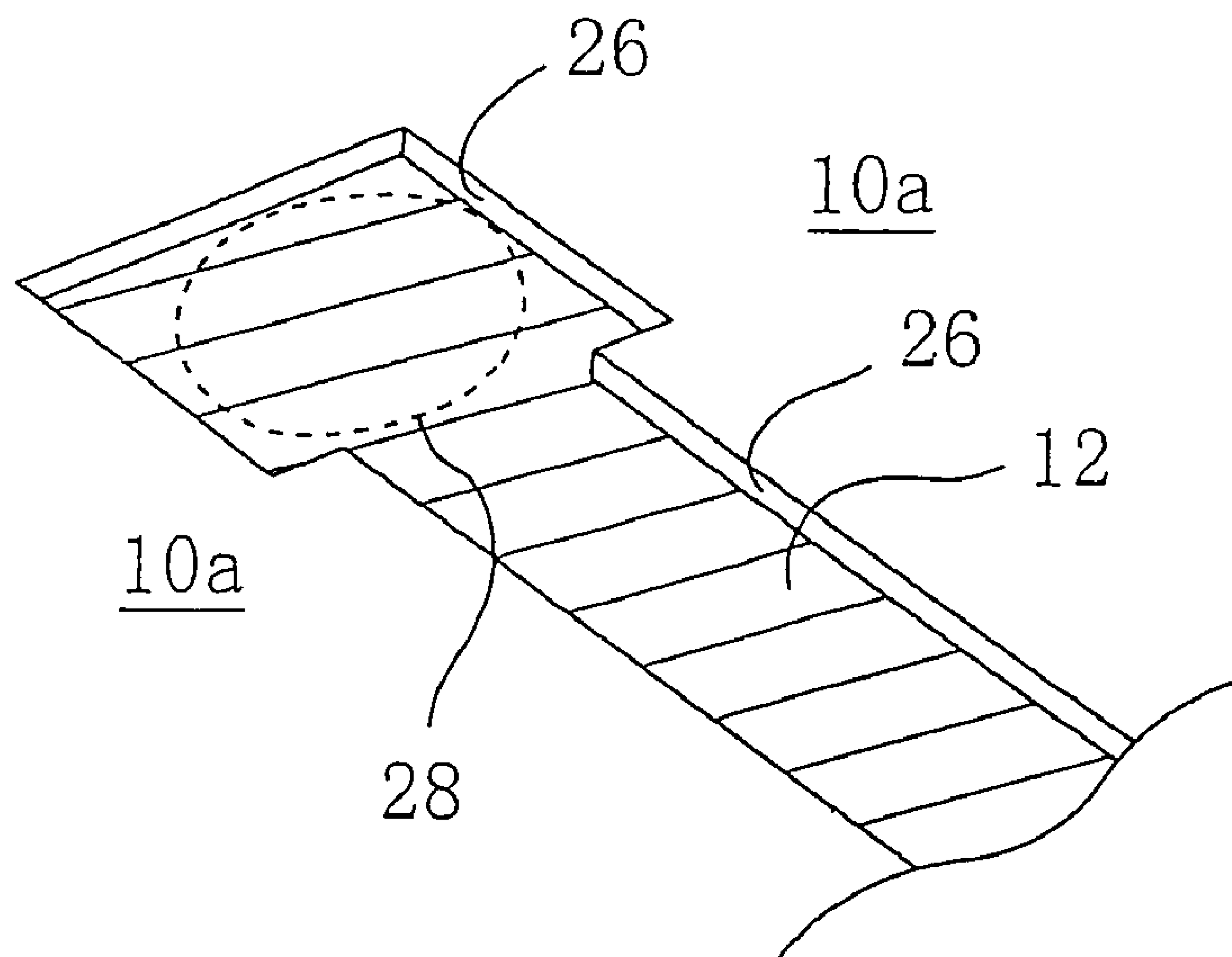

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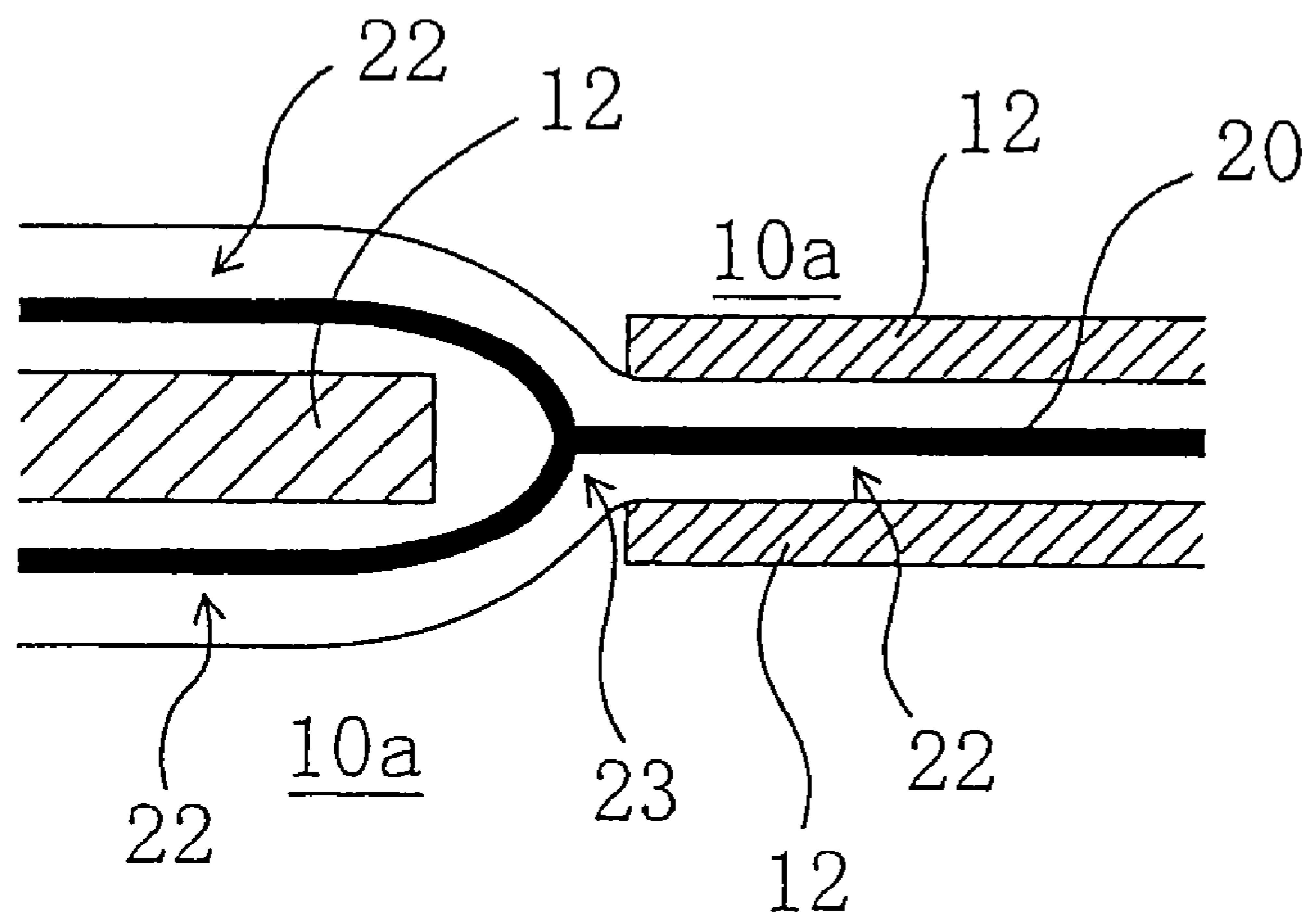

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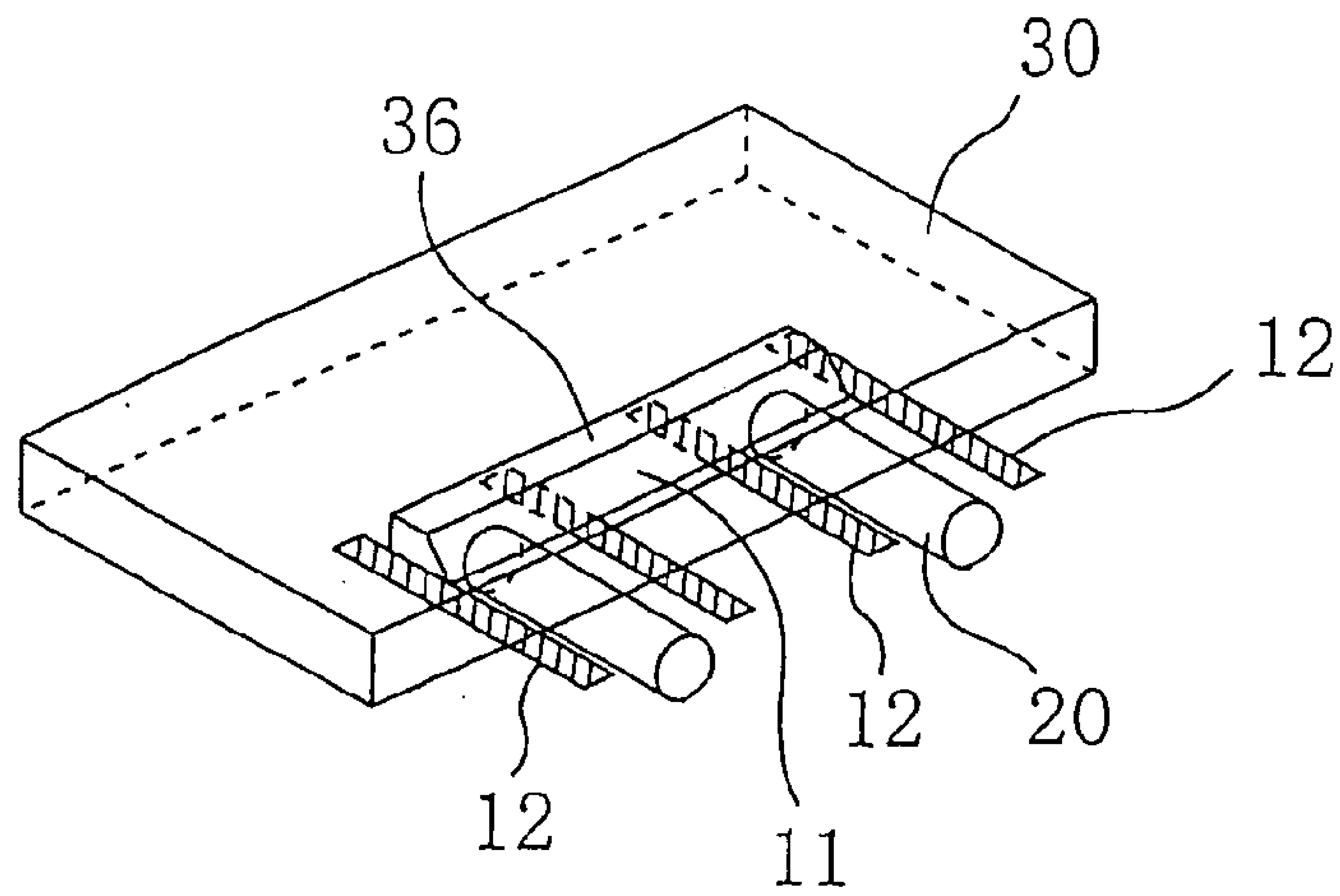

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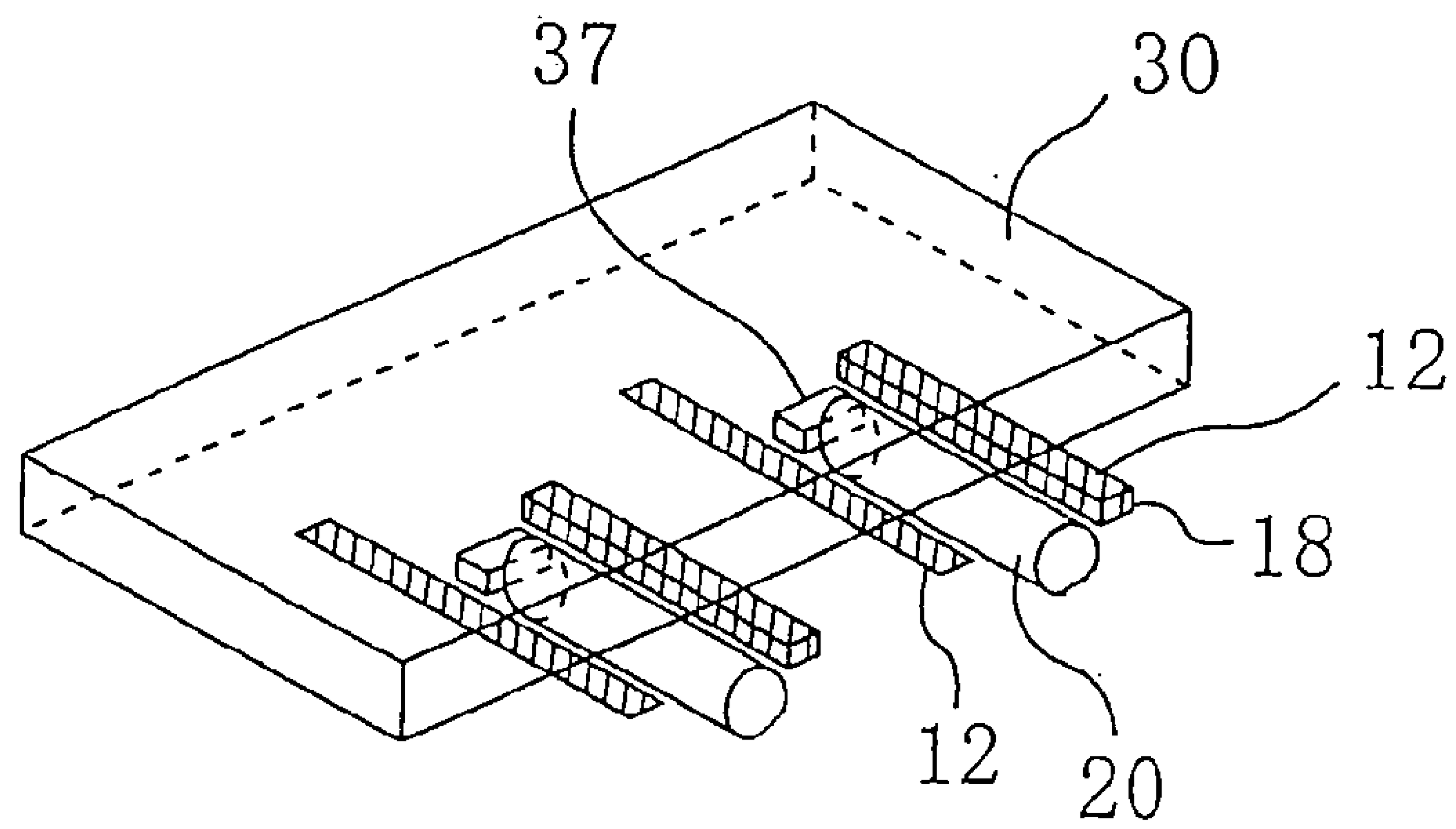

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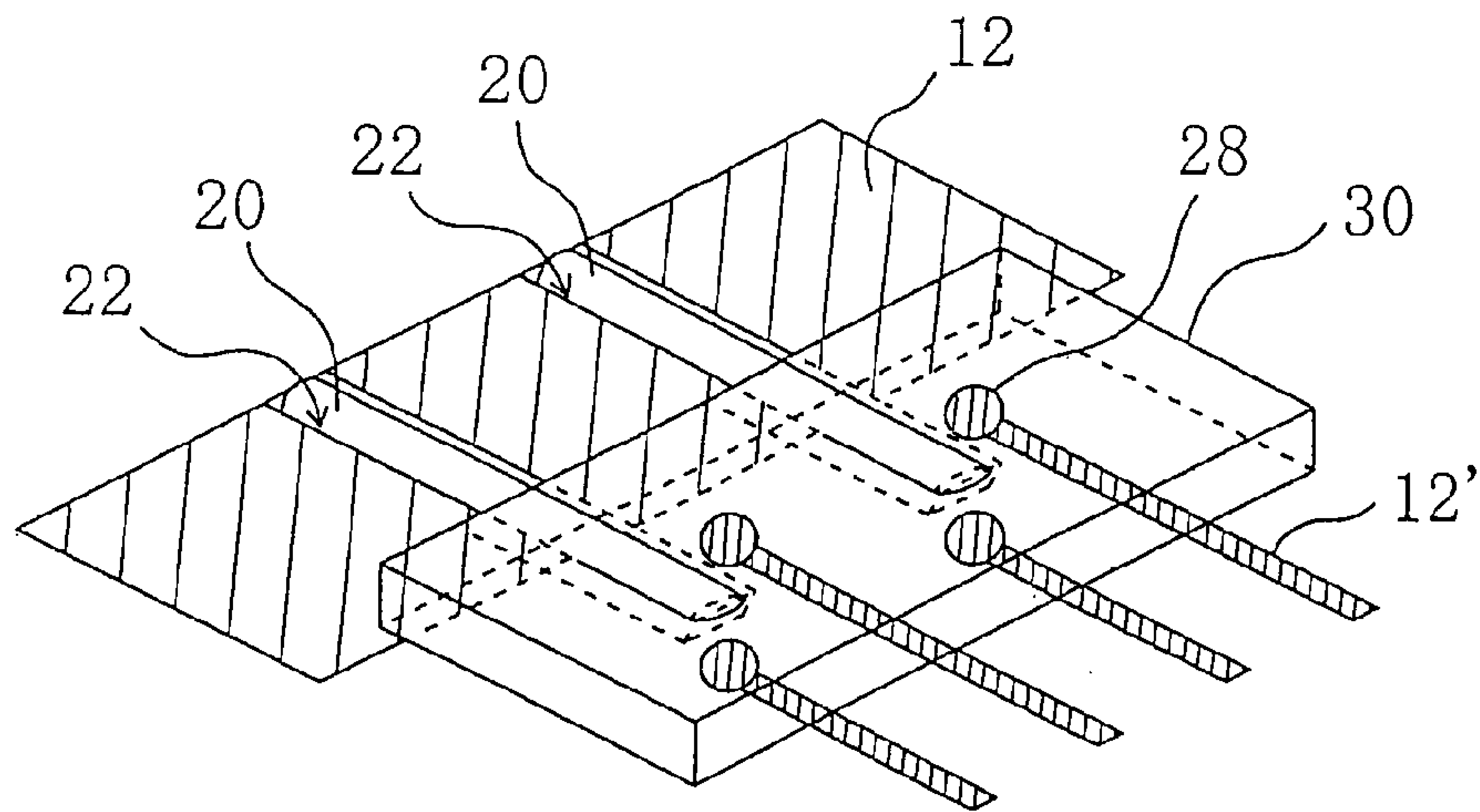

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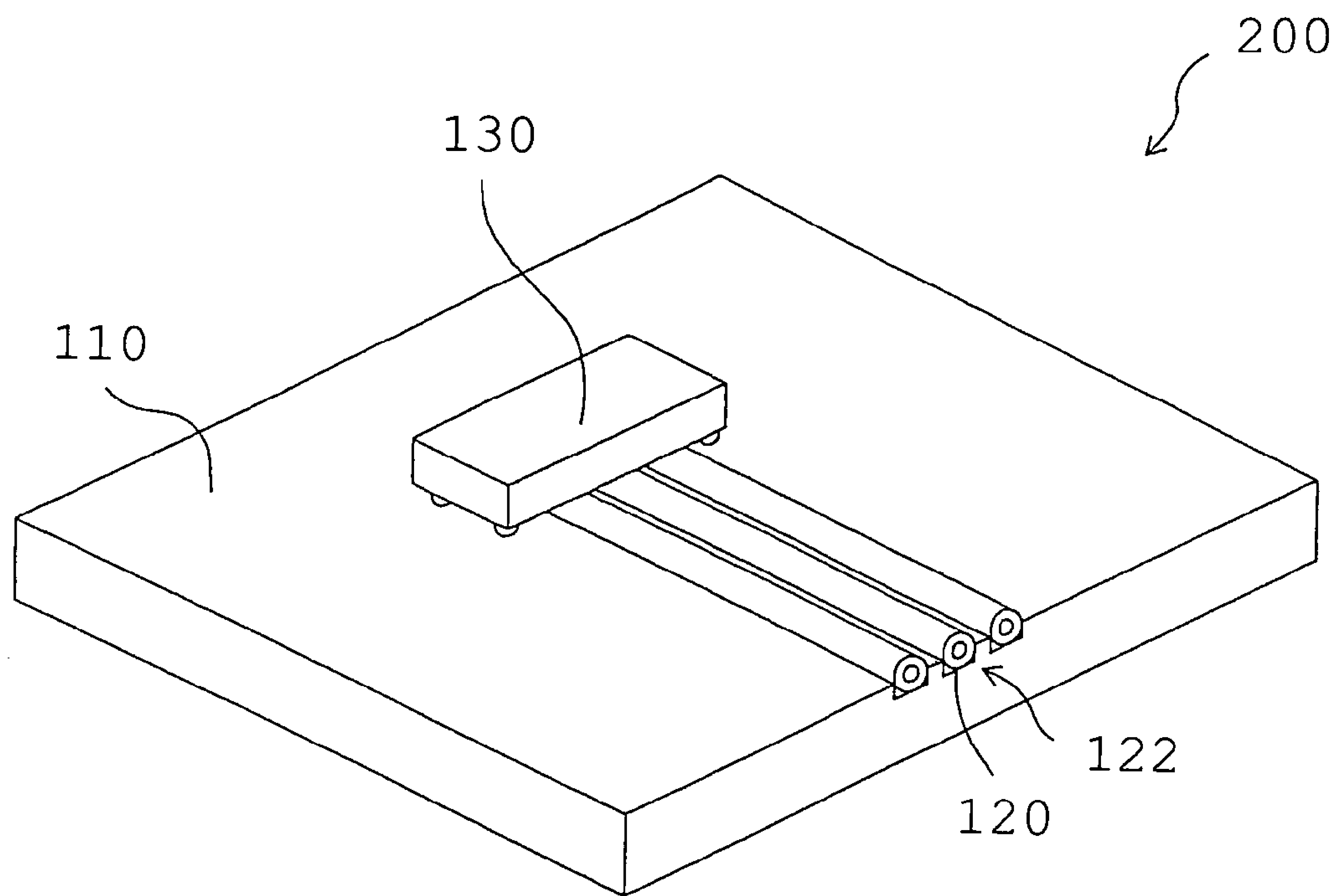

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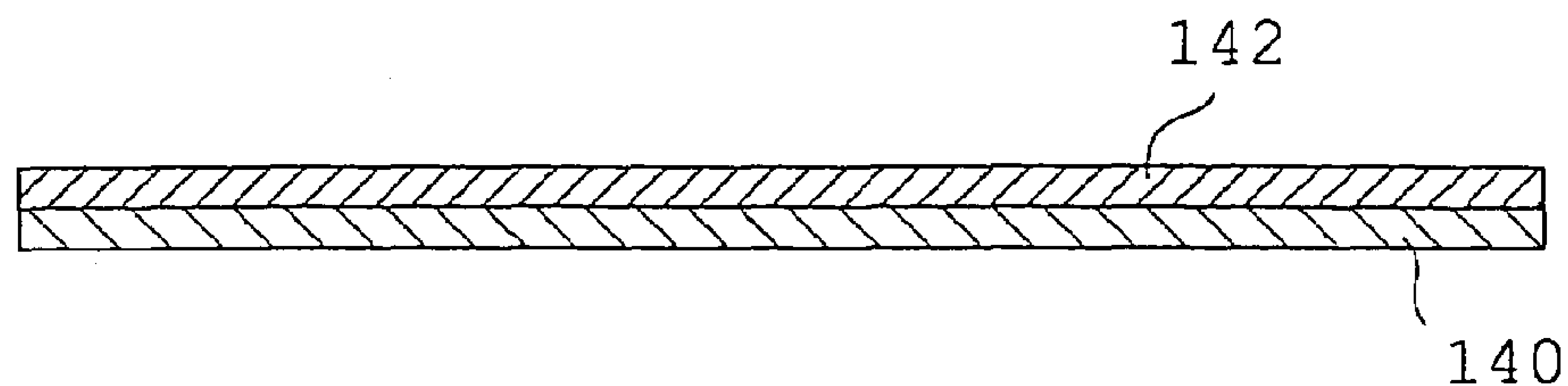

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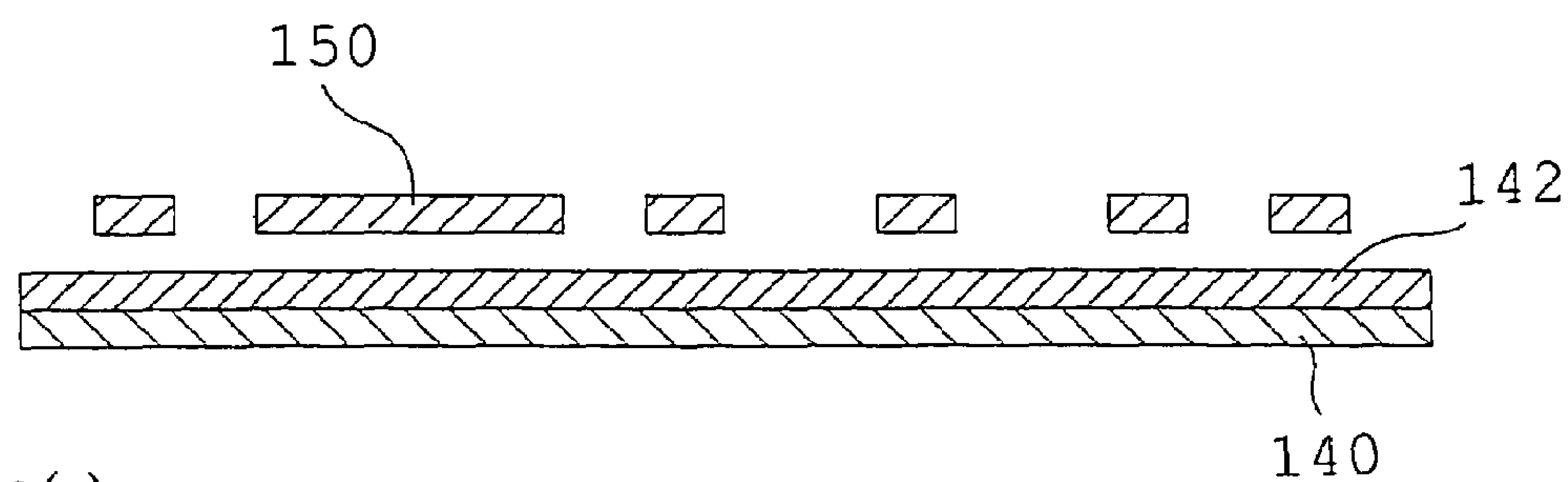

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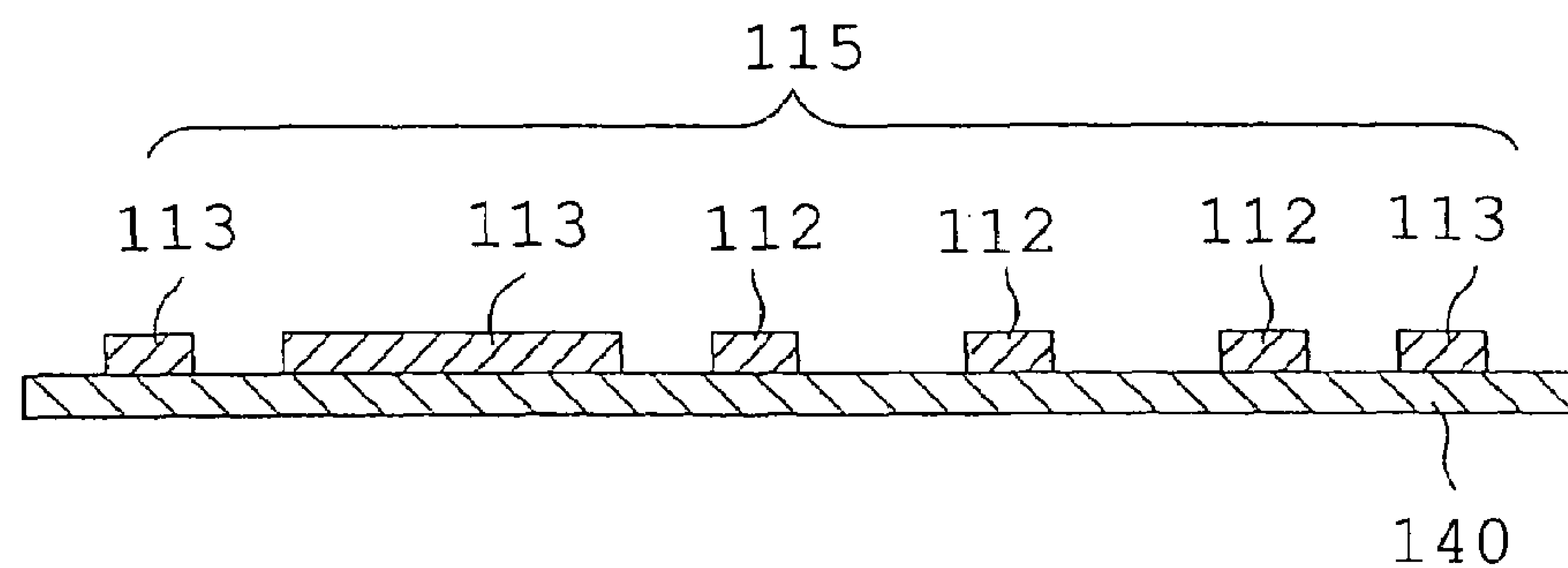

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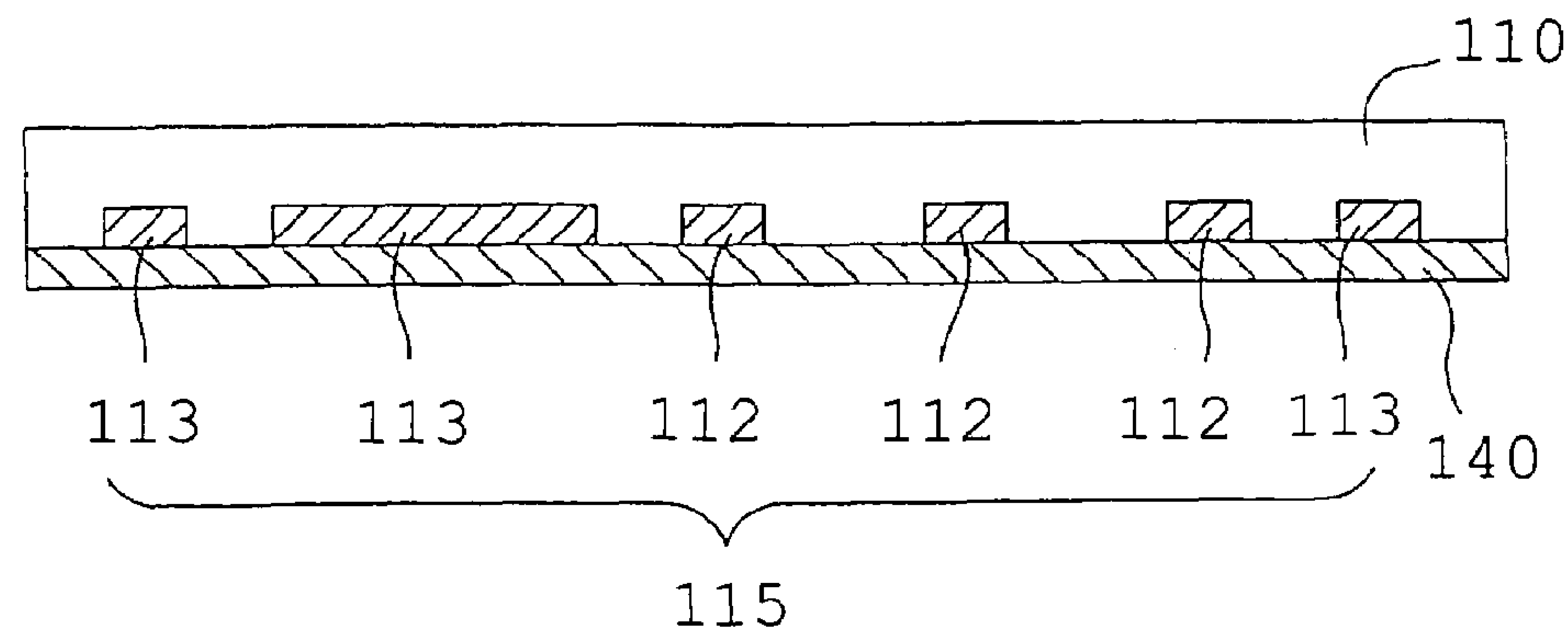

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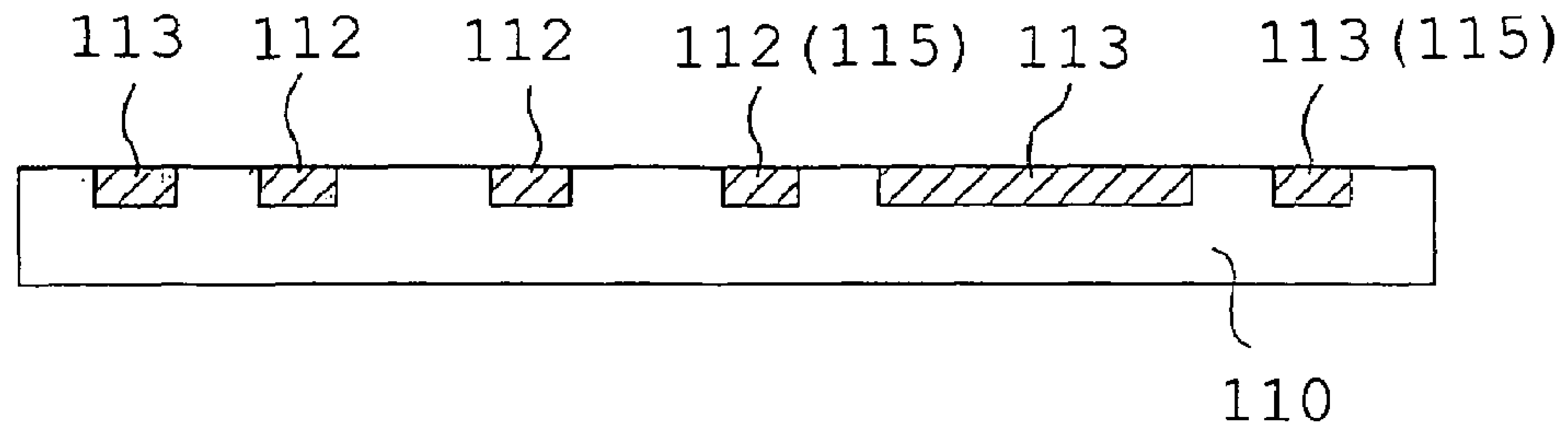

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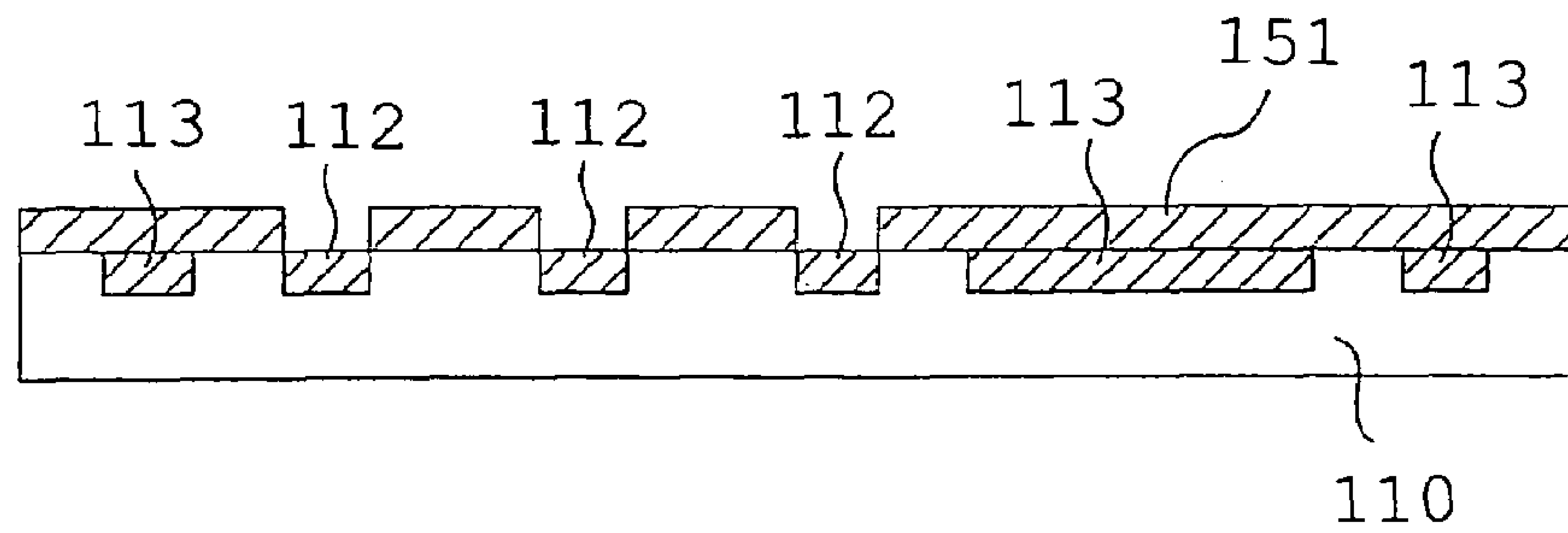

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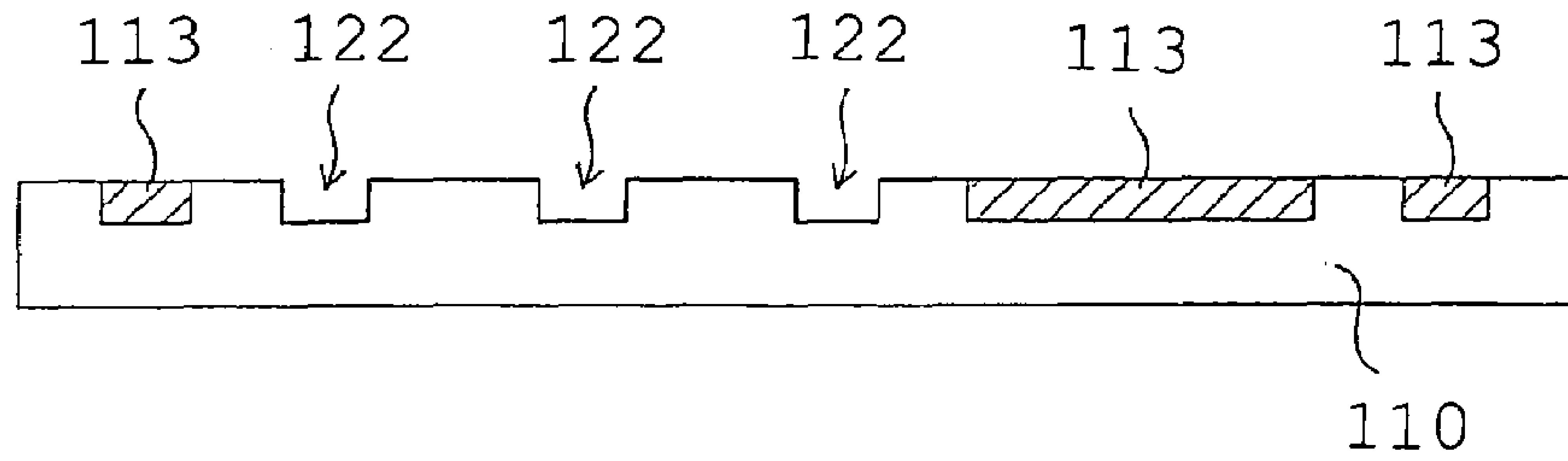

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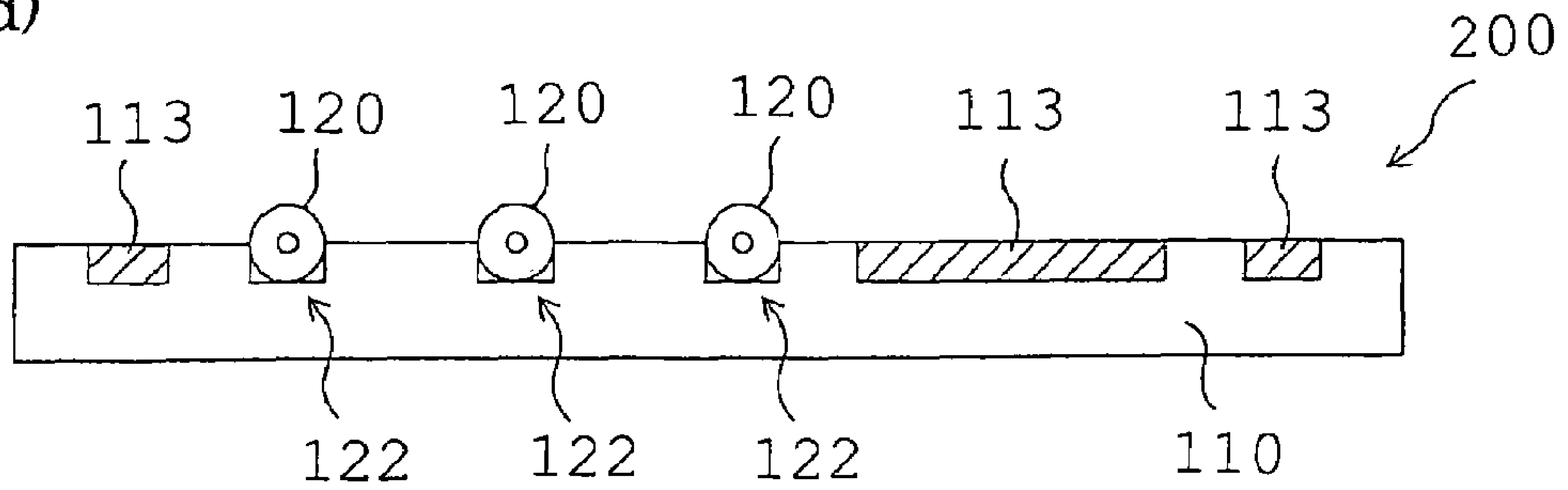

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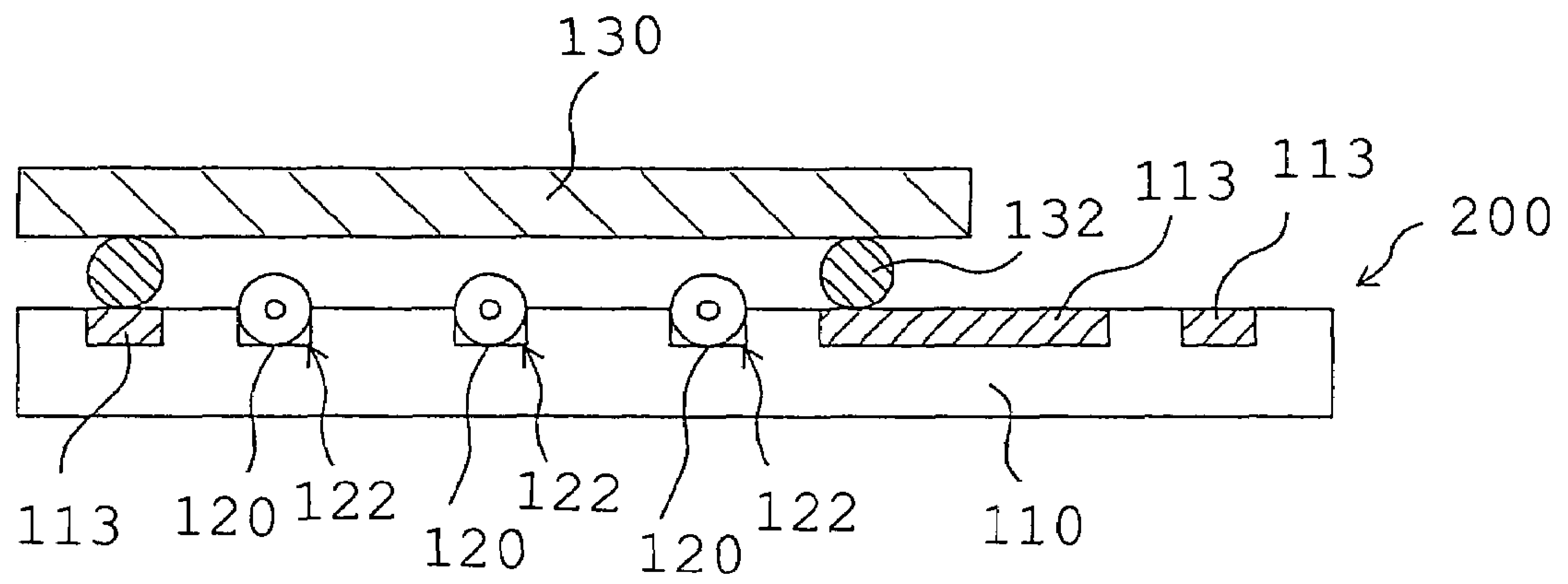

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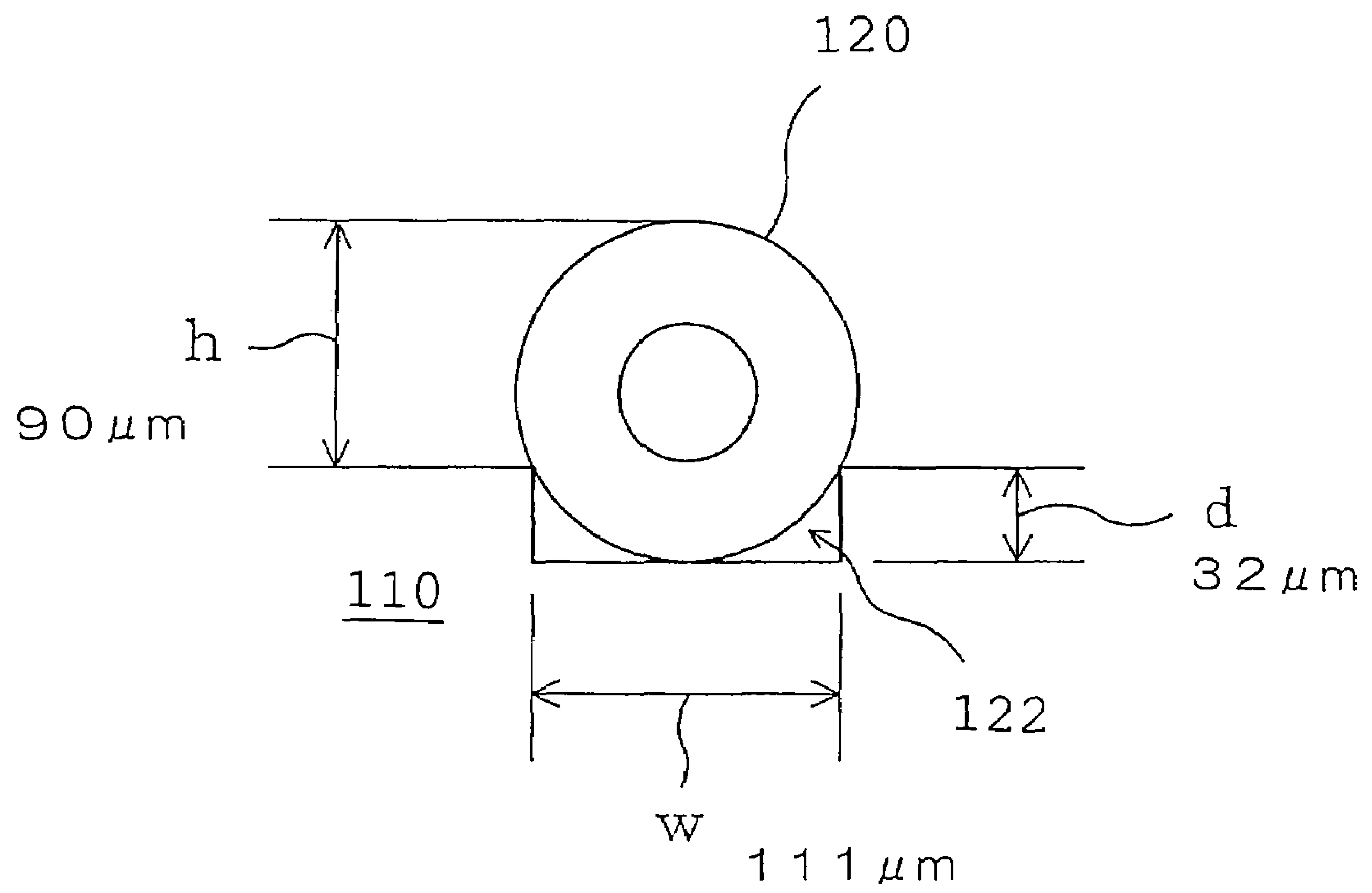

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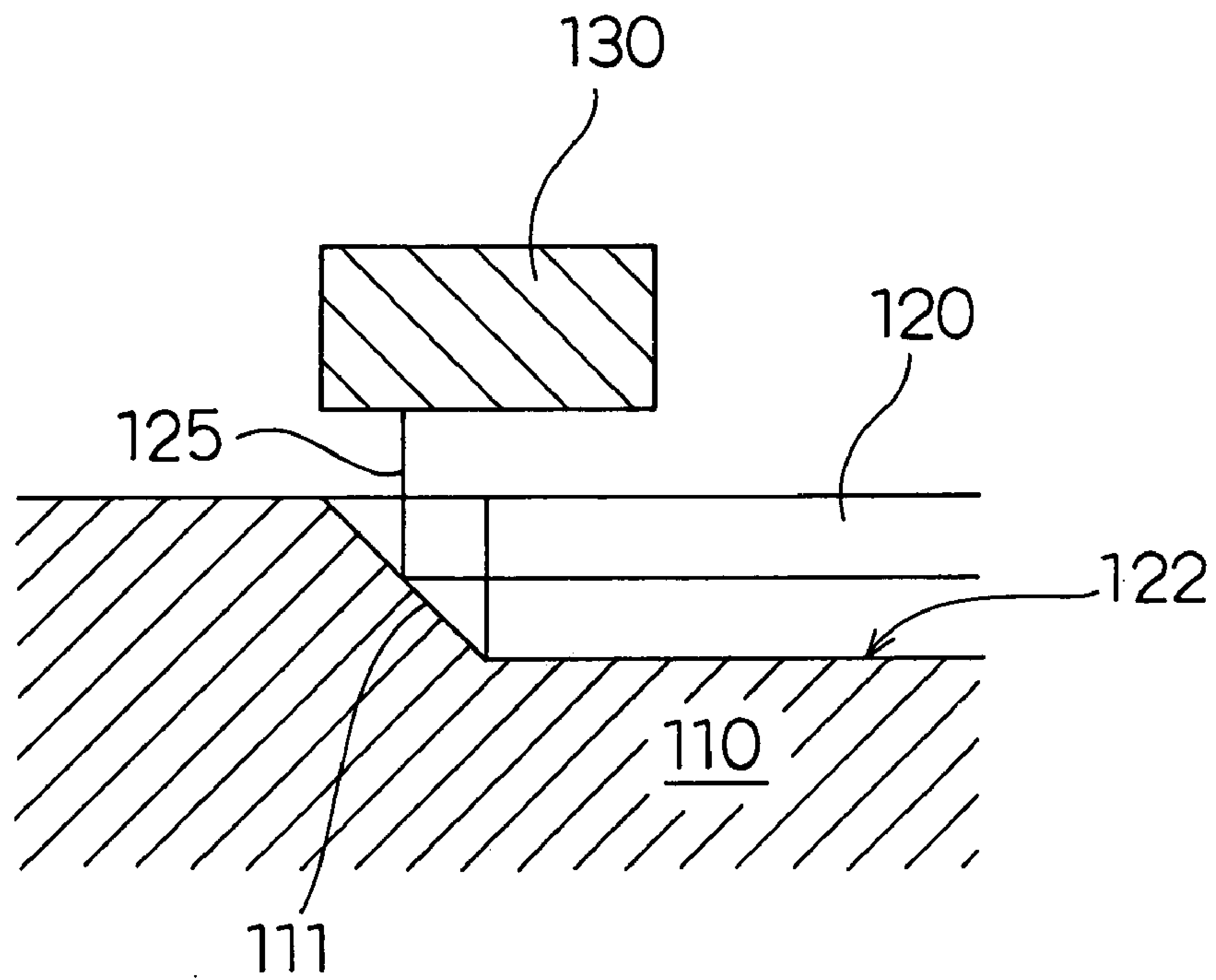

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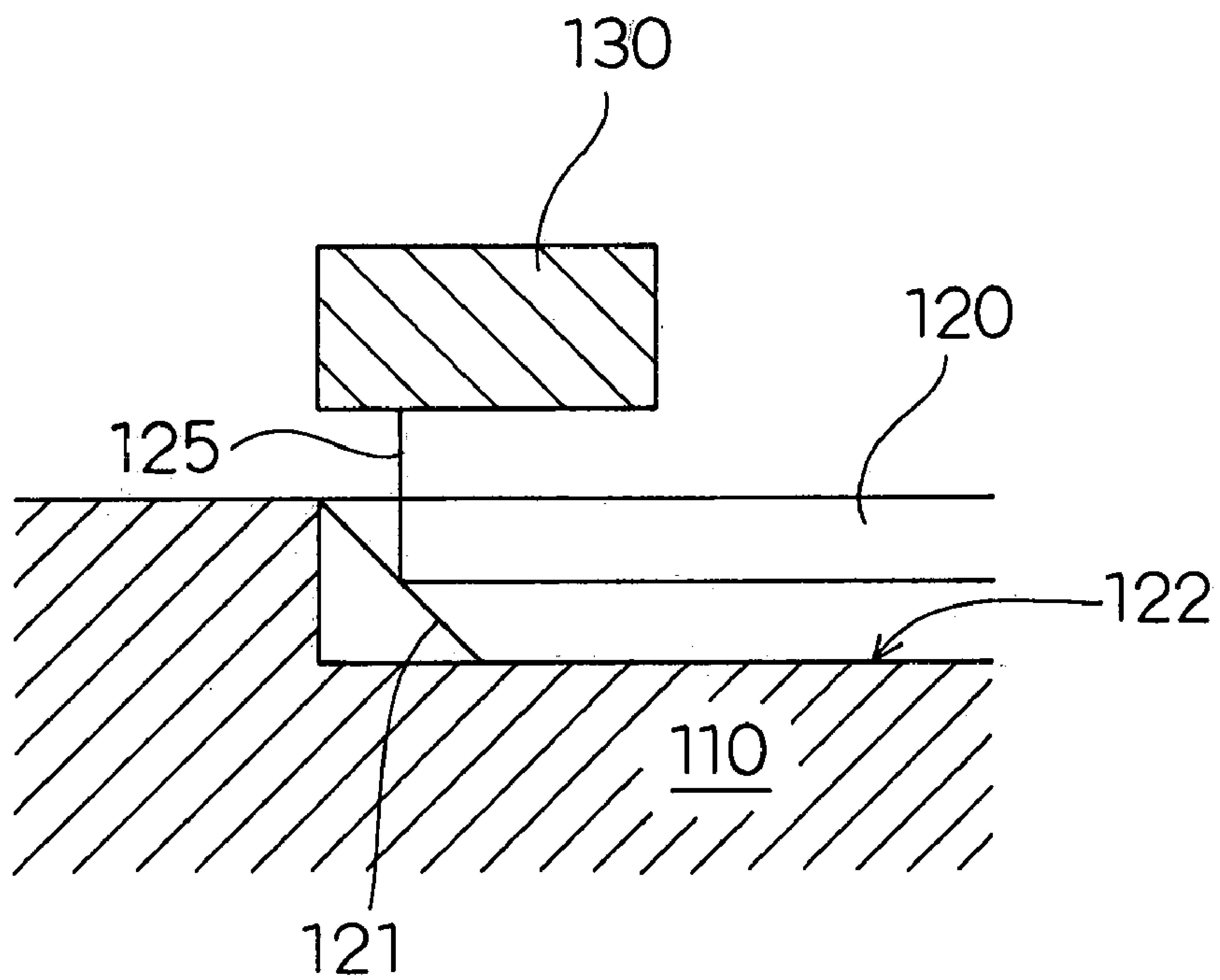

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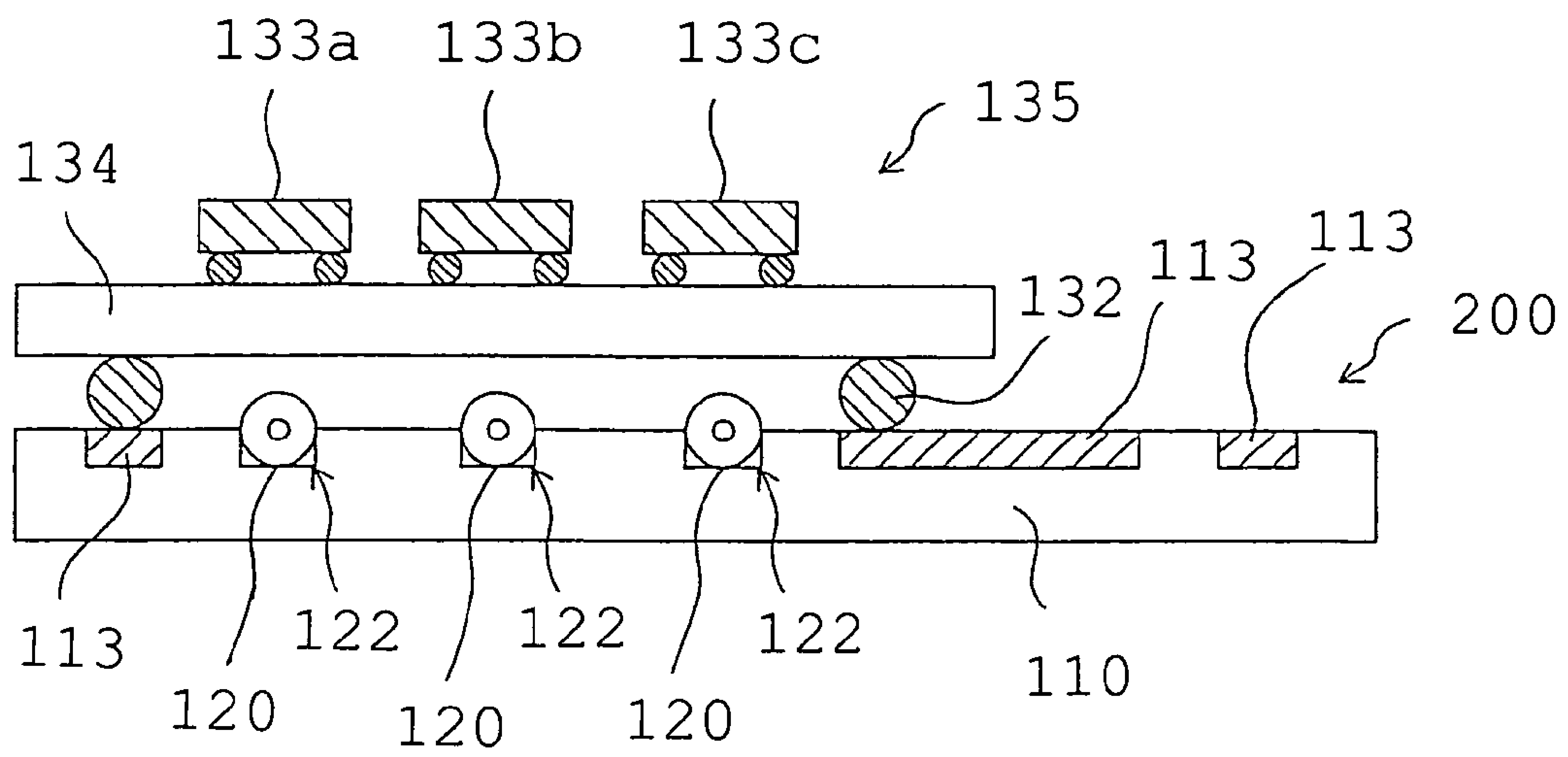

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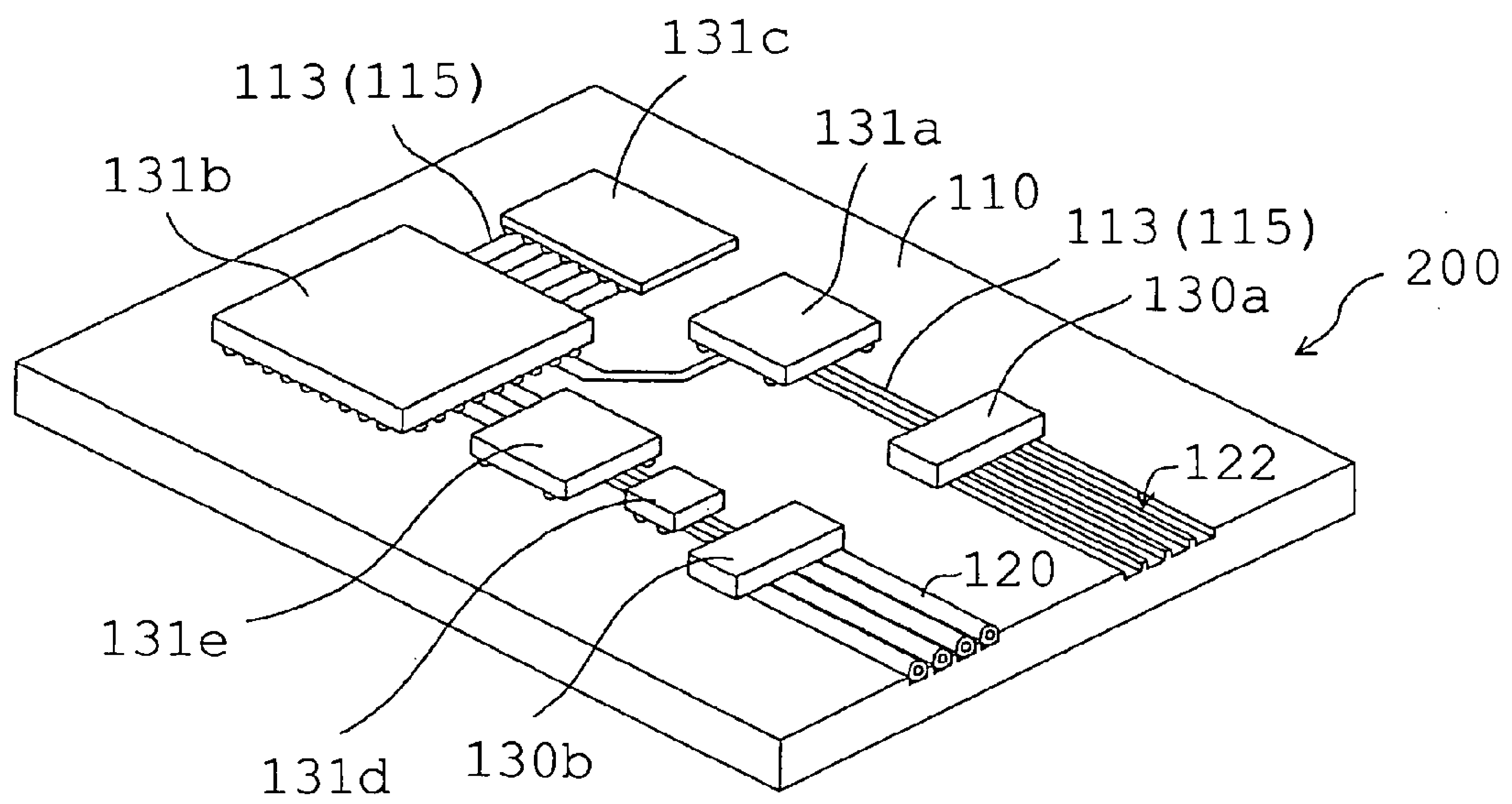

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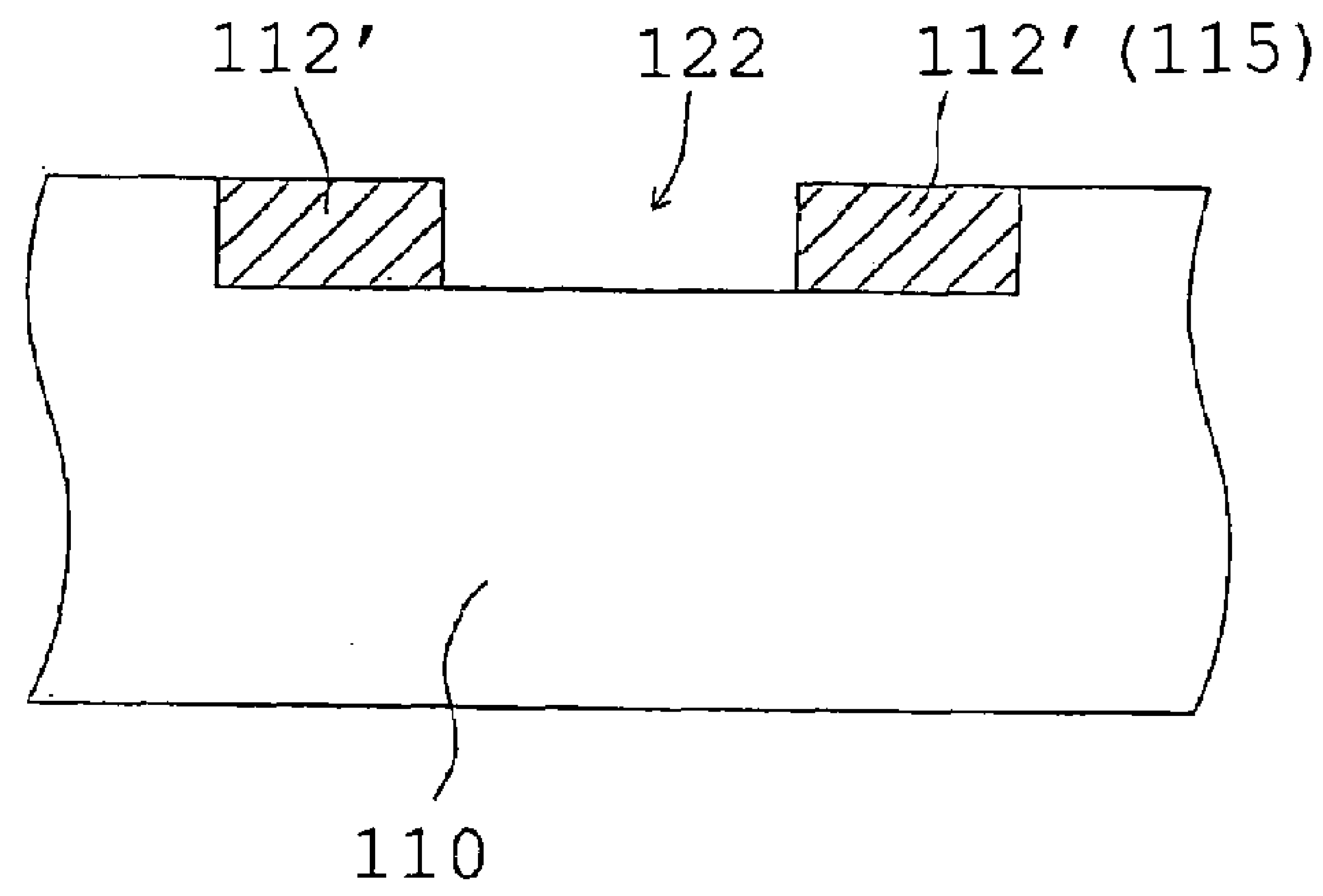

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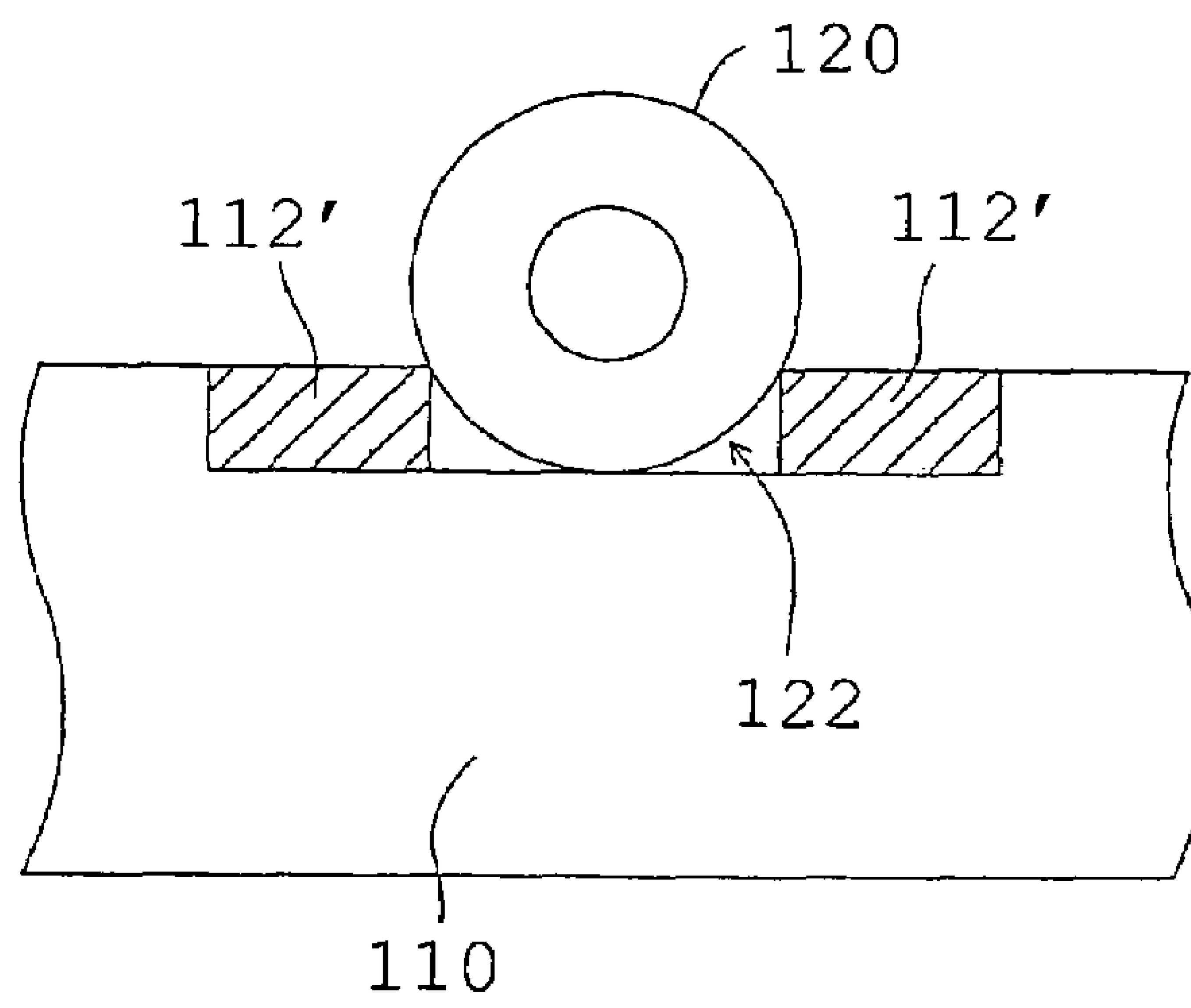

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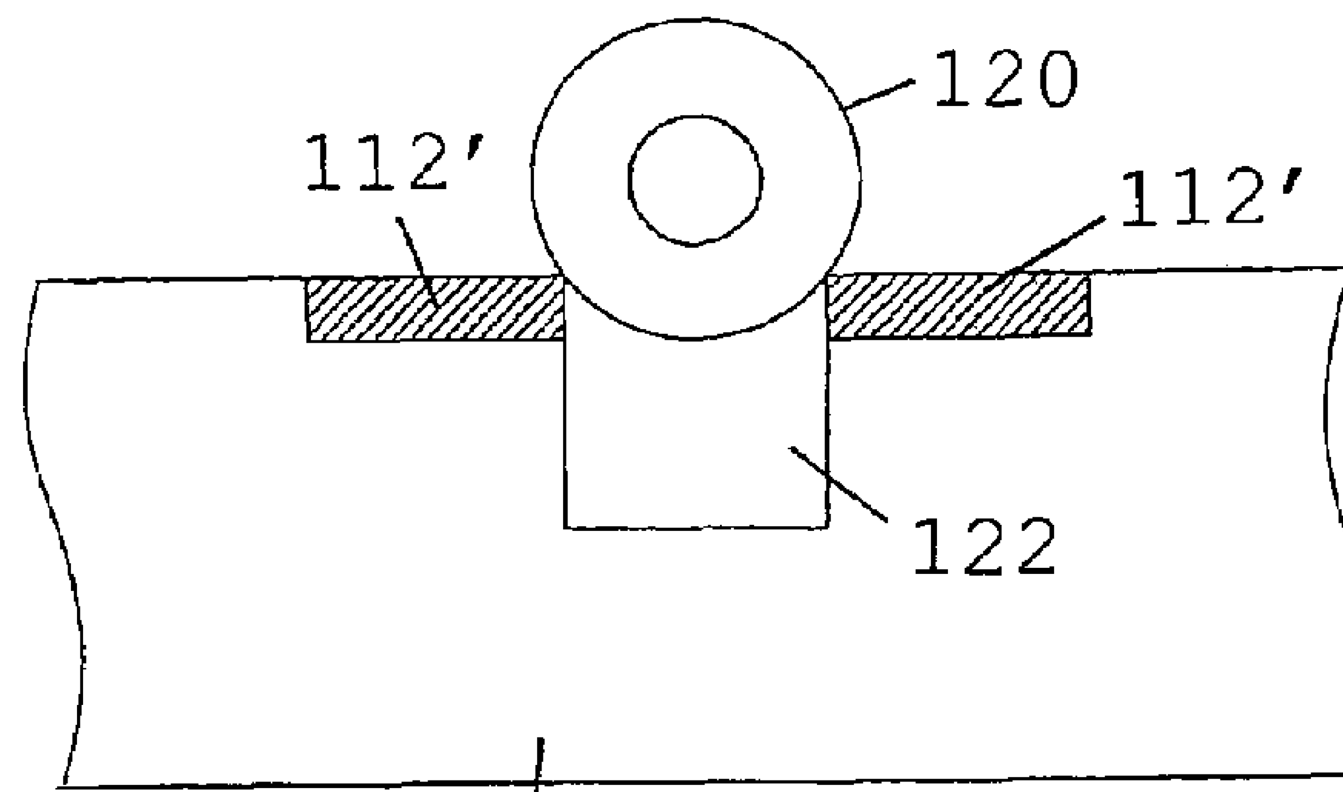

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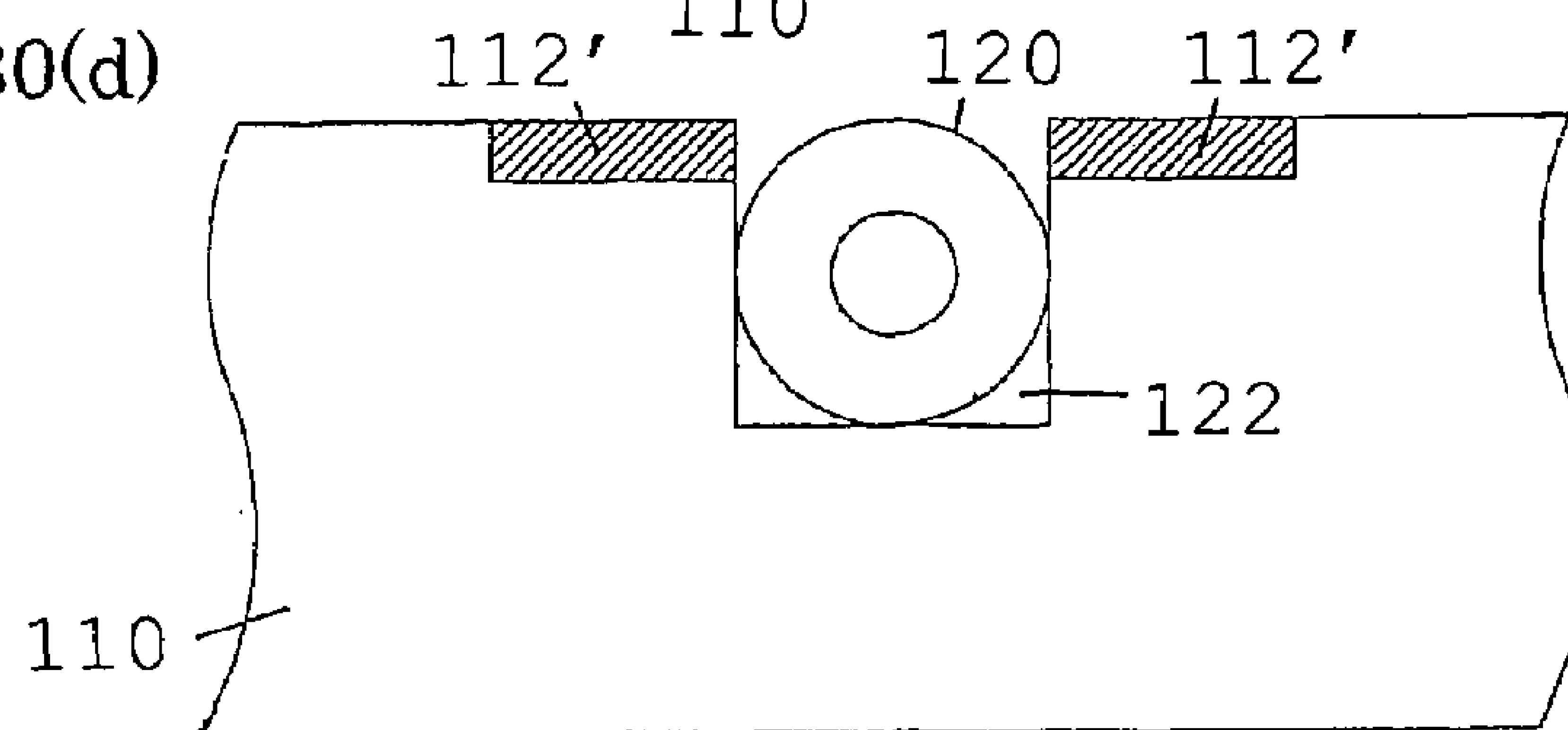

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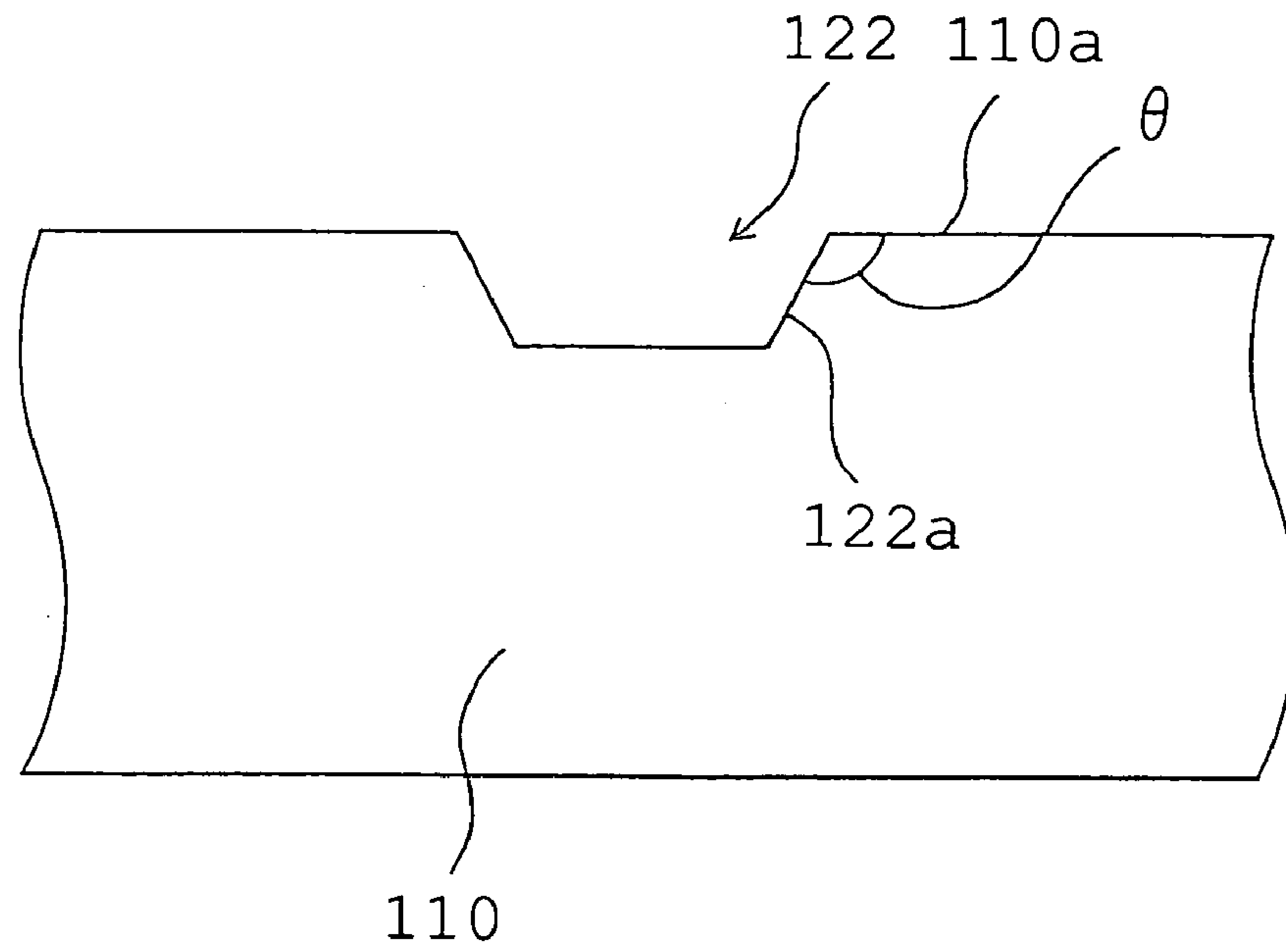

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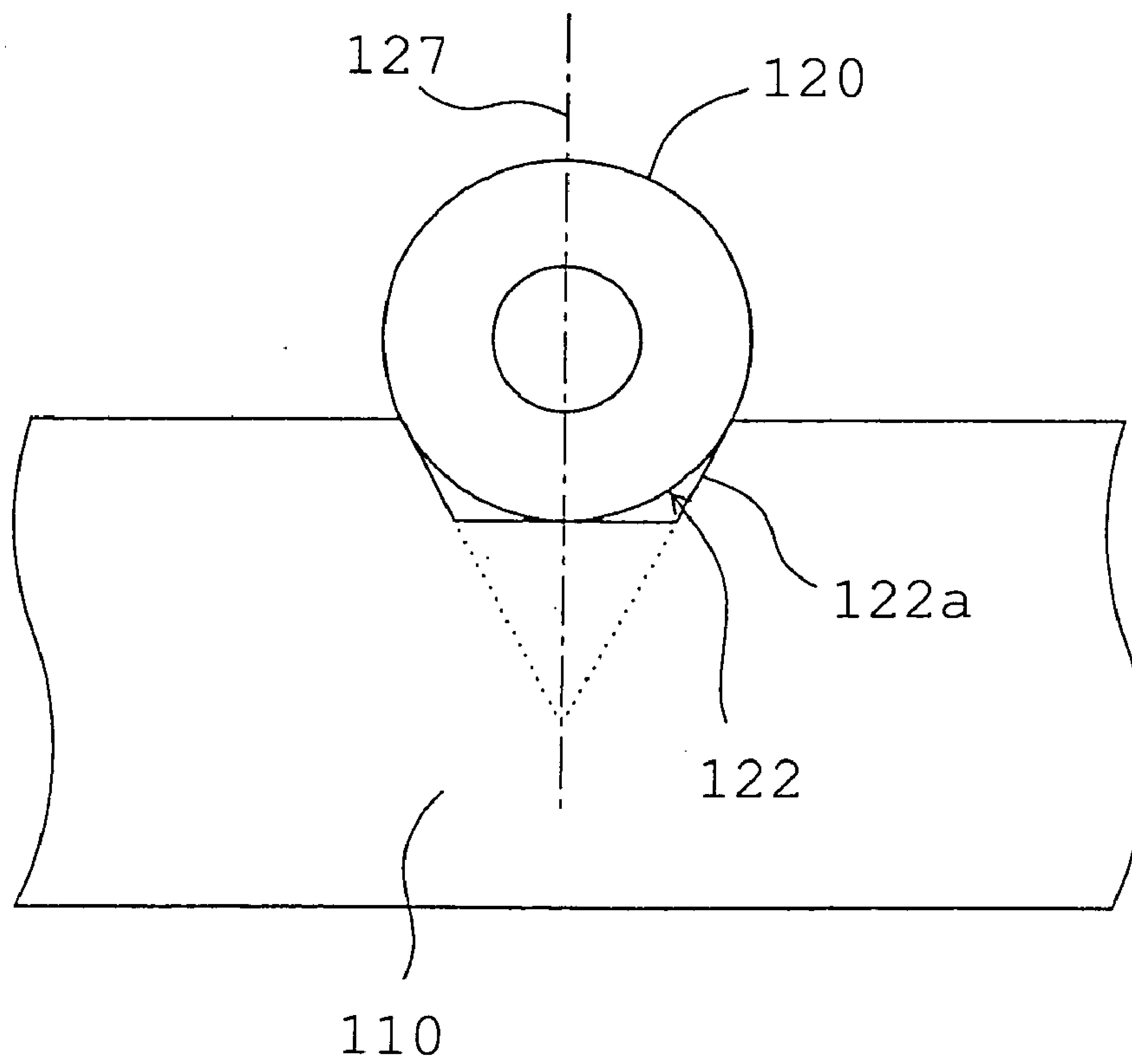
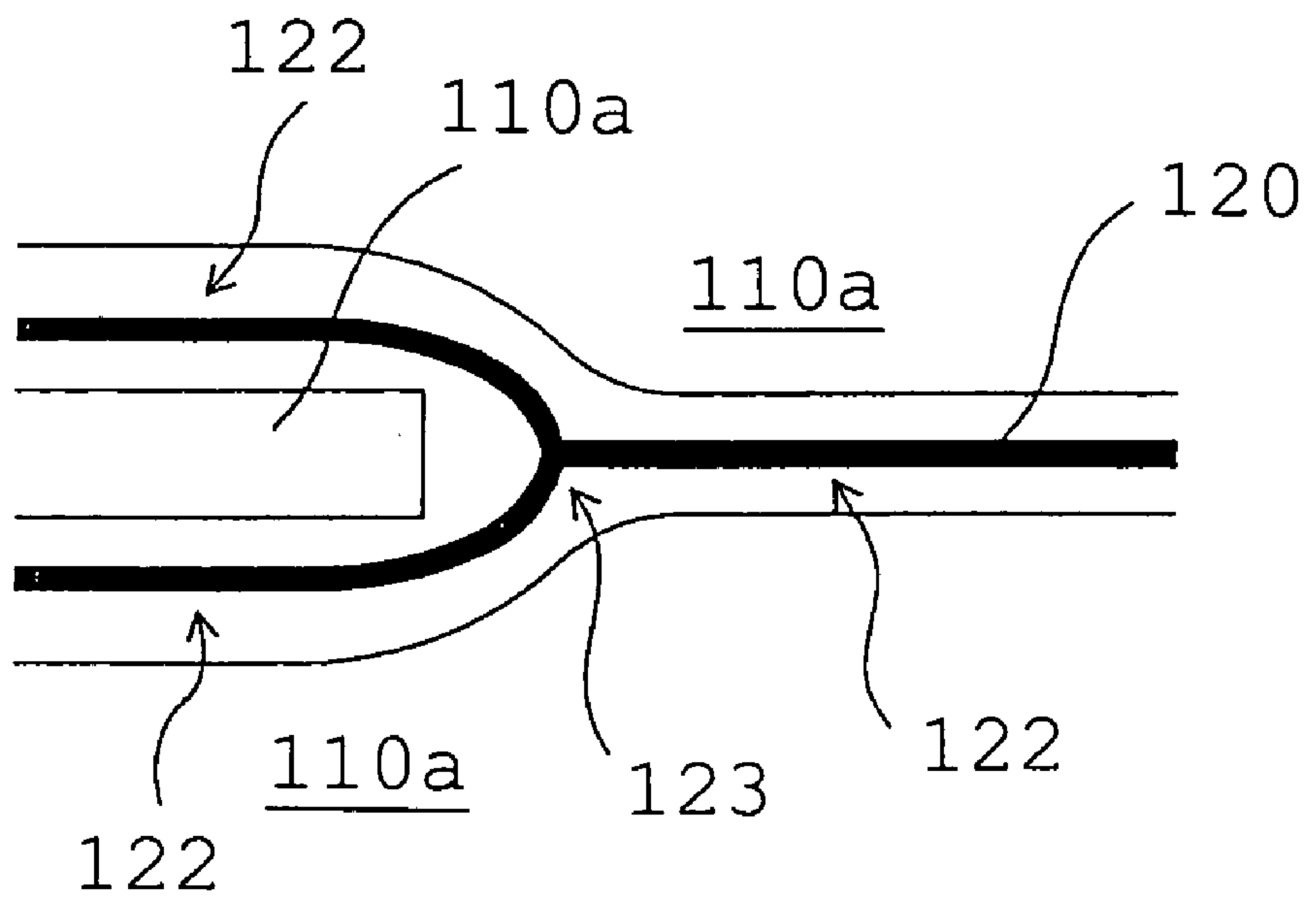


Fig.32



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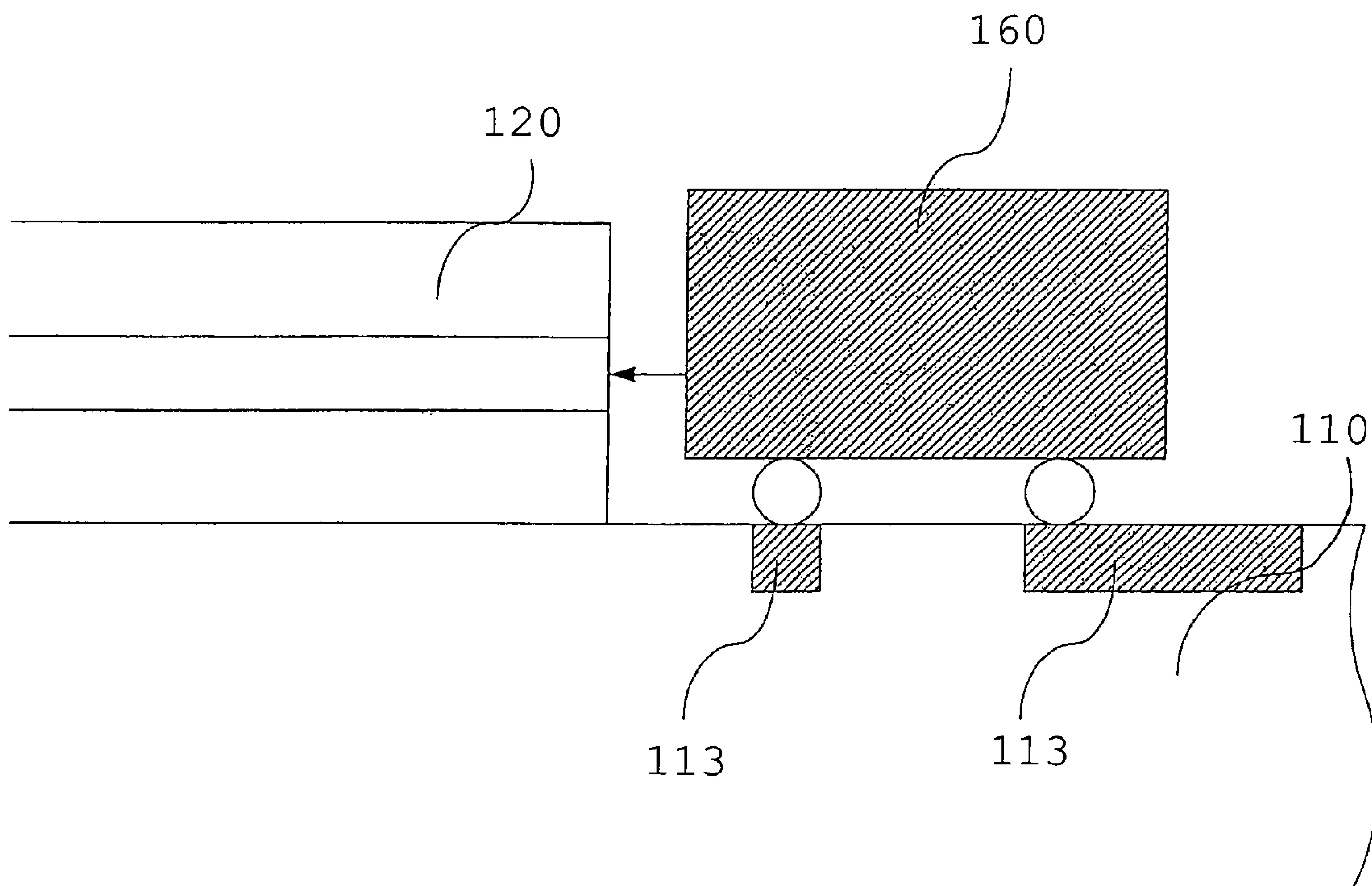
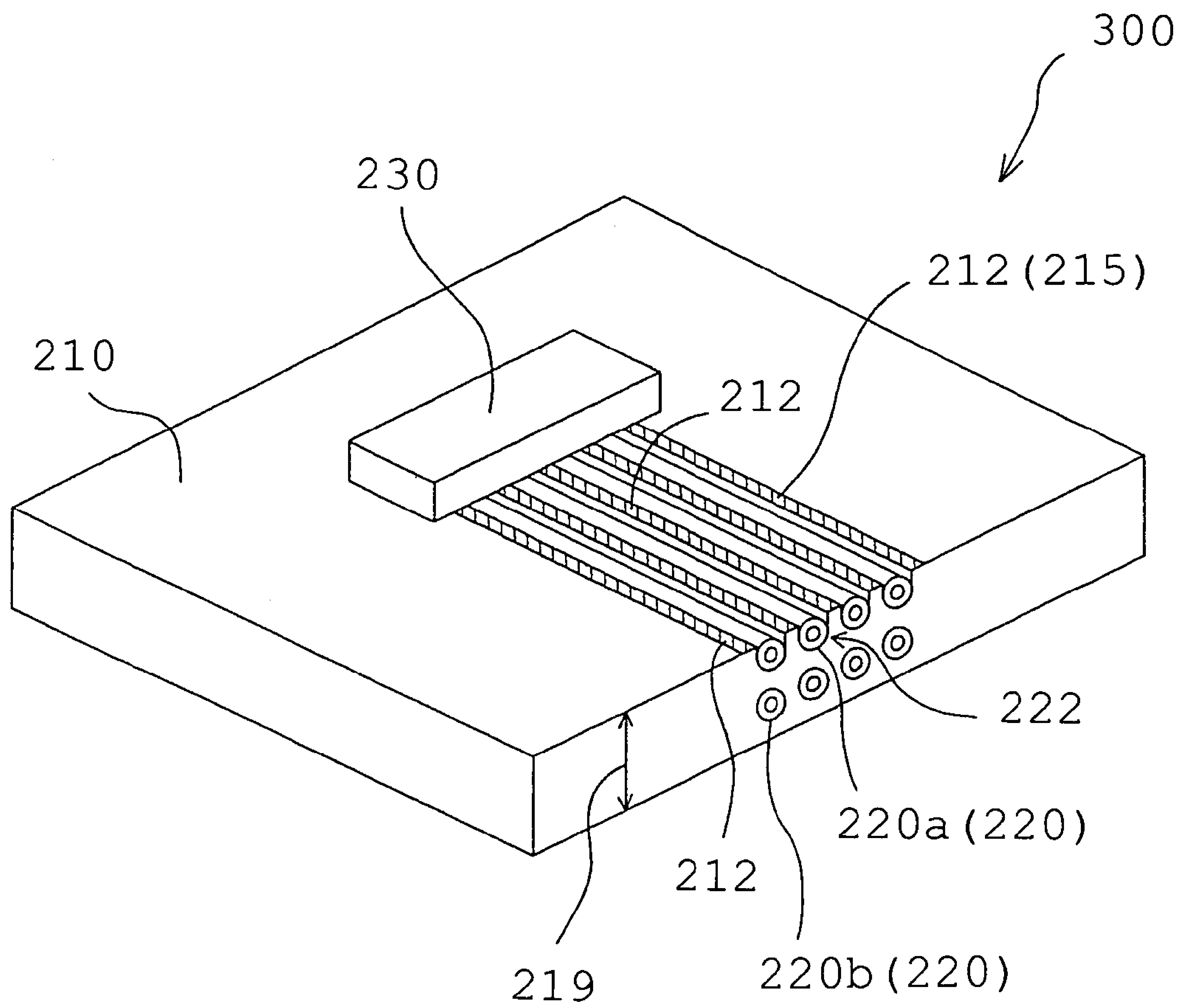


Fig.34



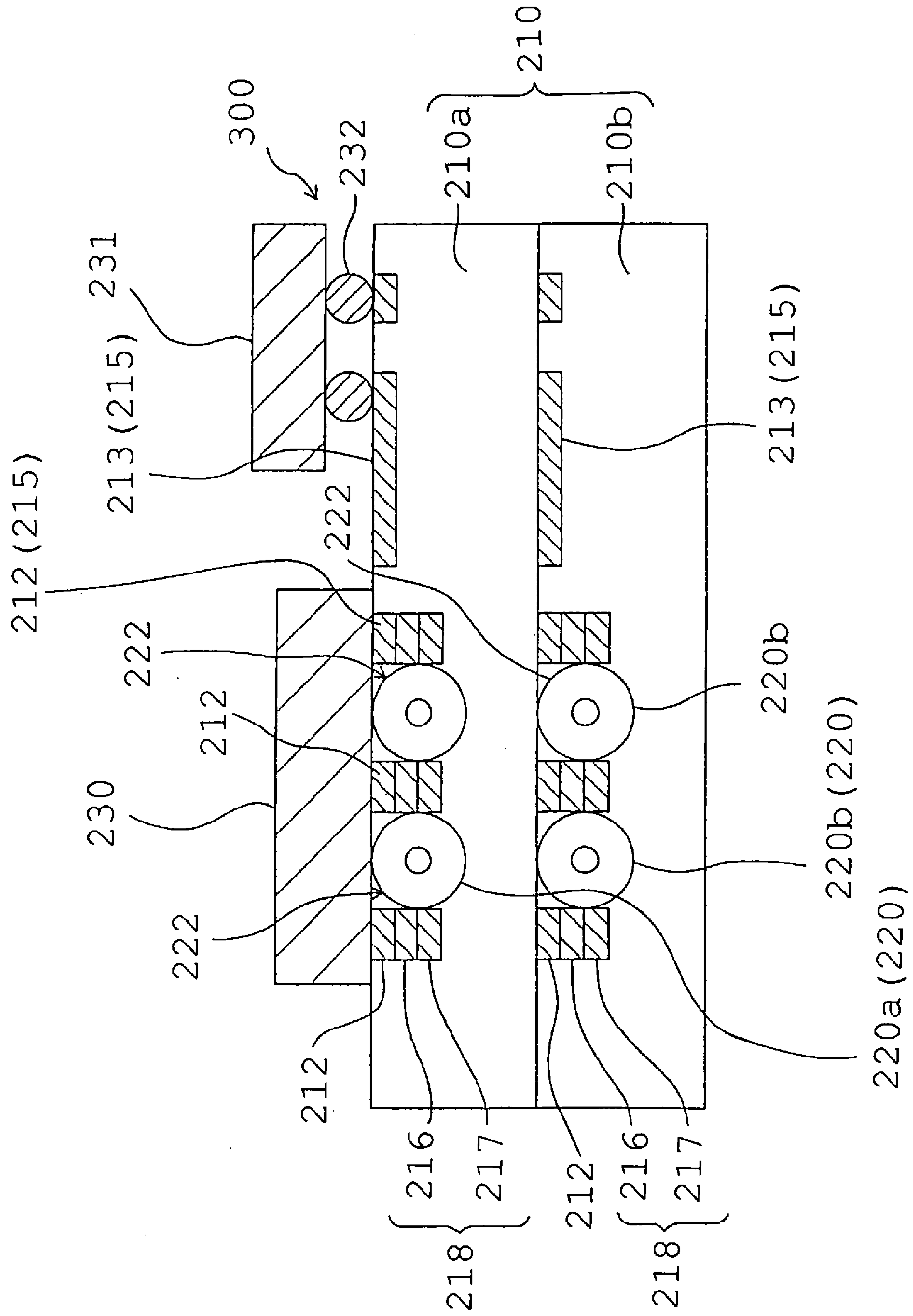


Fig.35

Fig.36

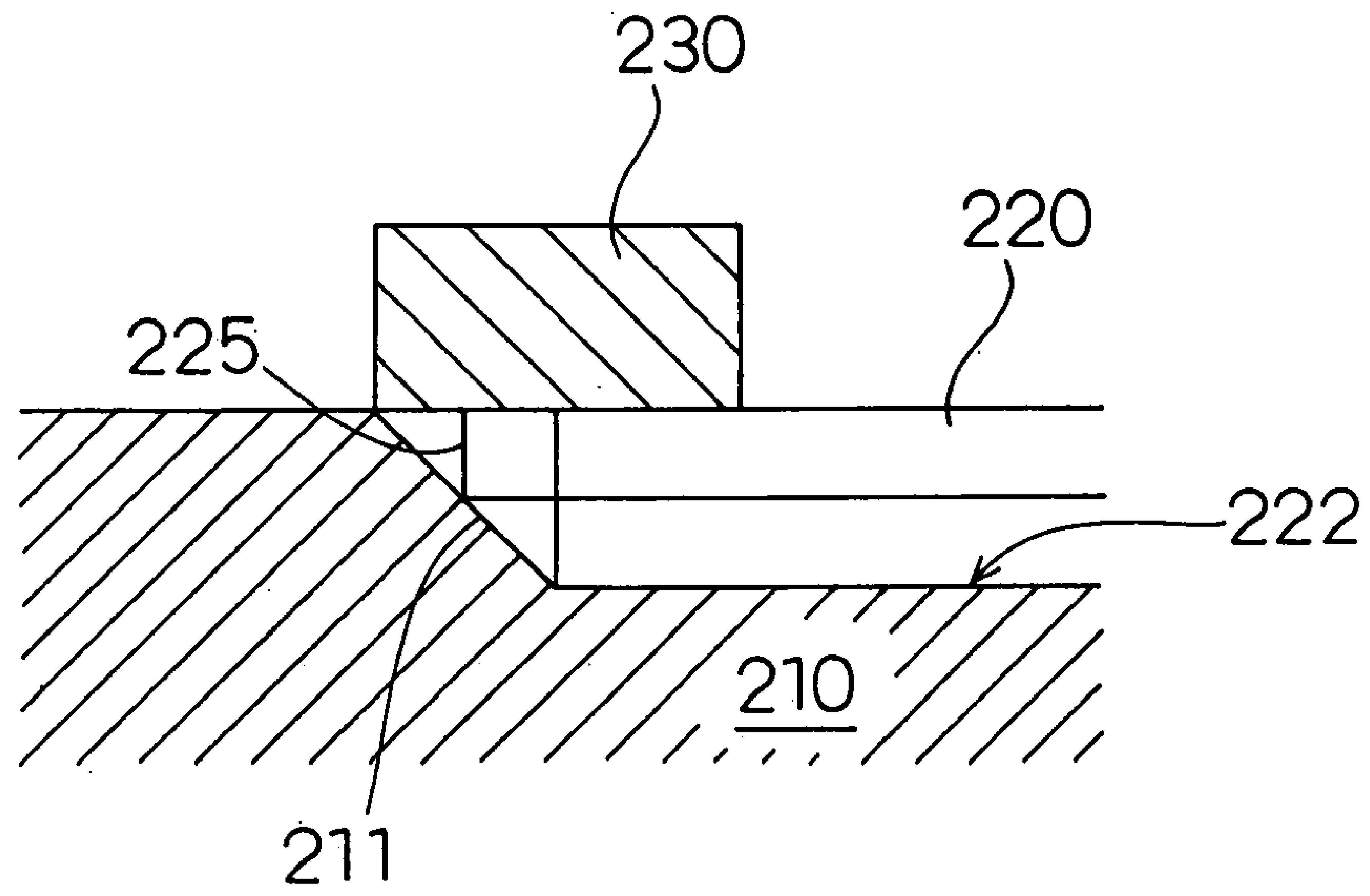


Fig.37

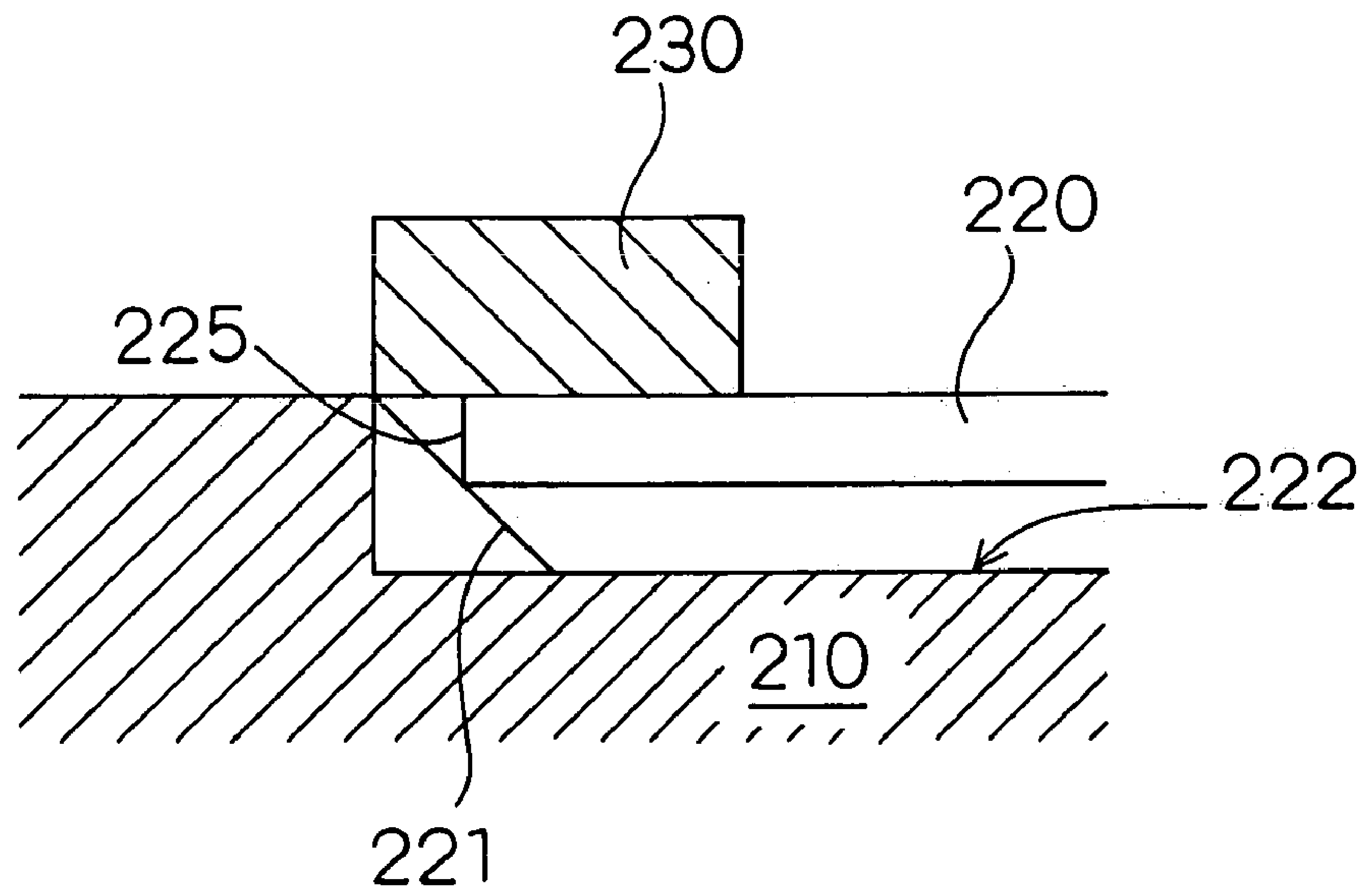


Fig.38

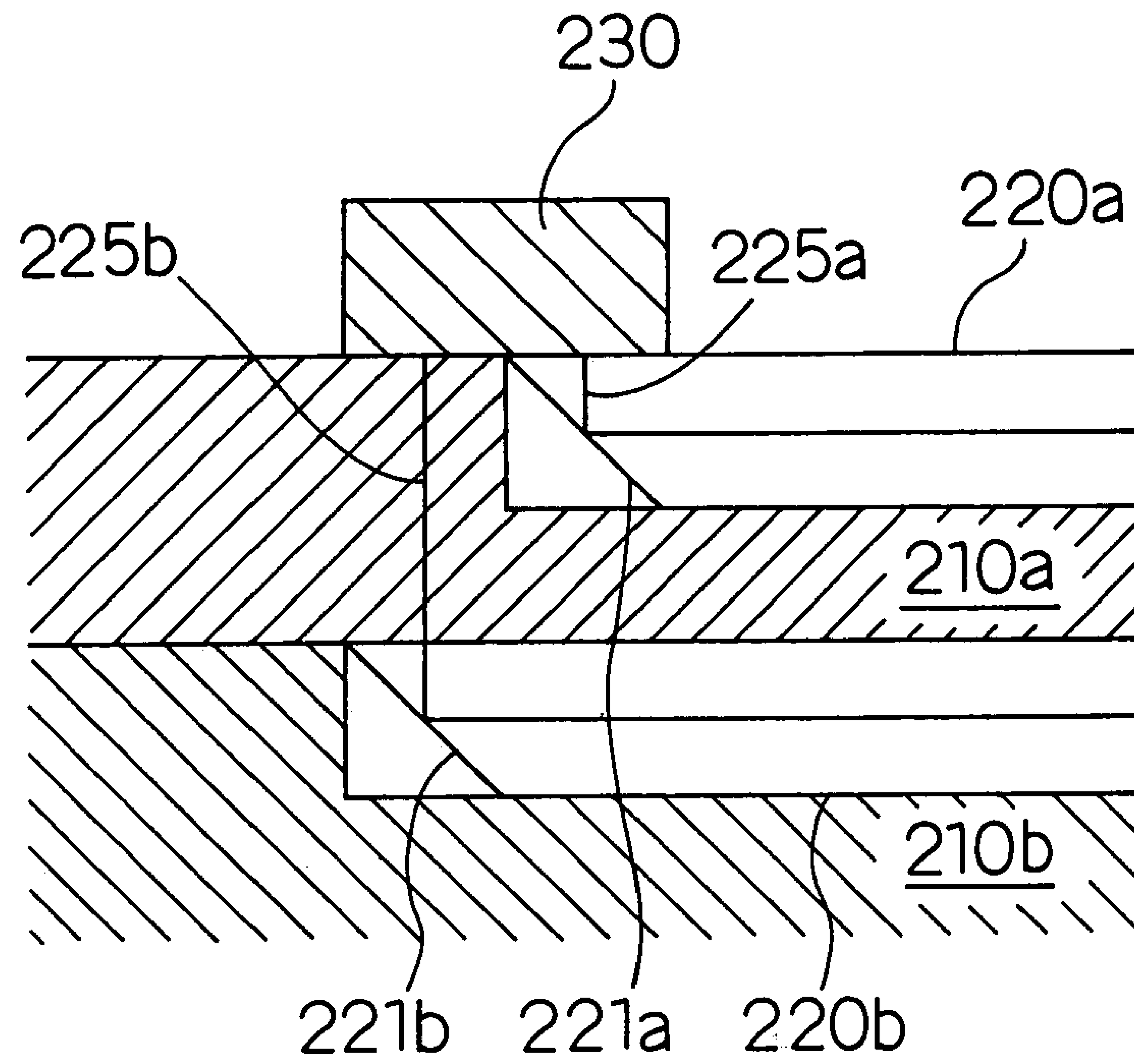


Fig.39

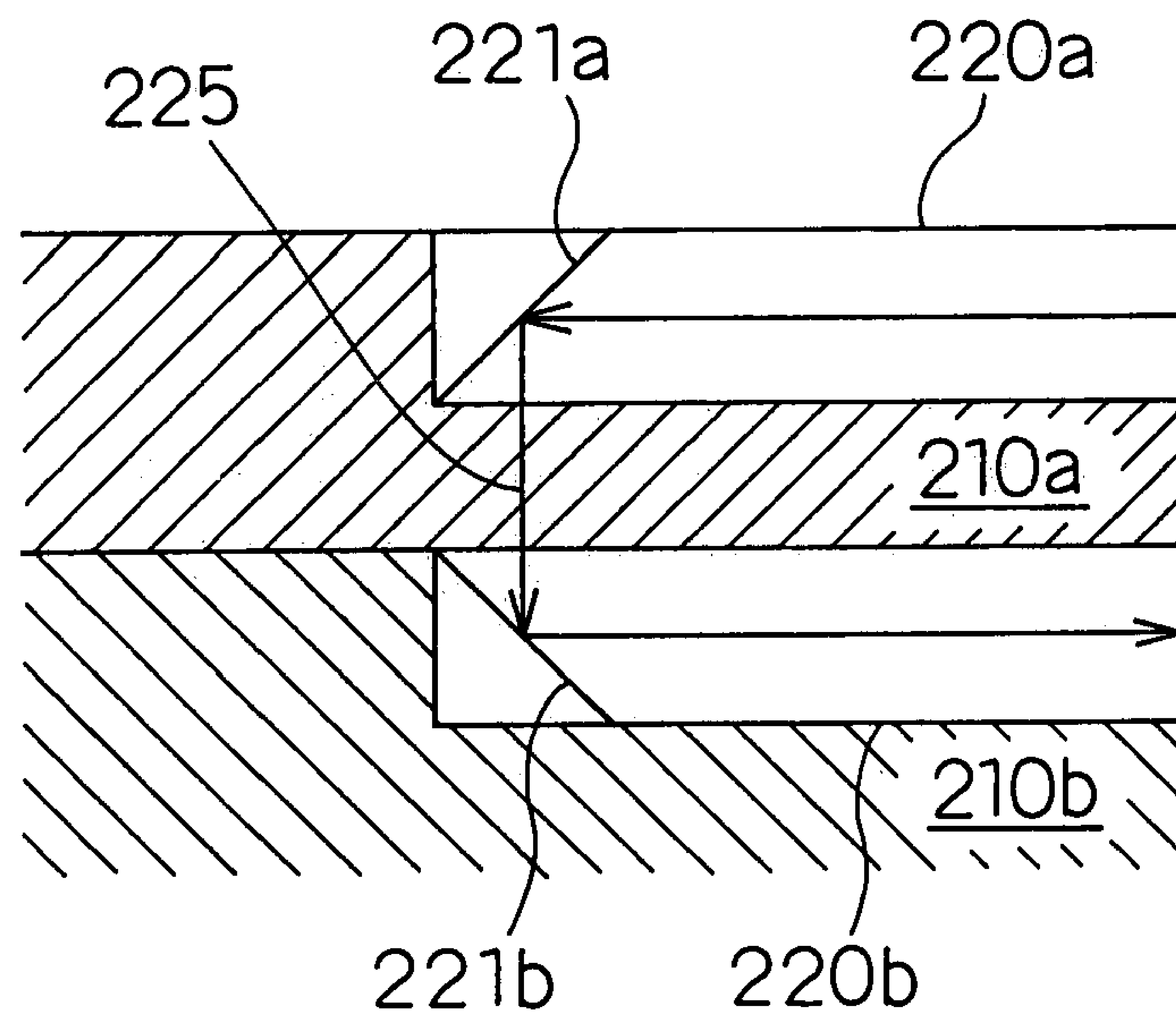


Fig.40 (a)

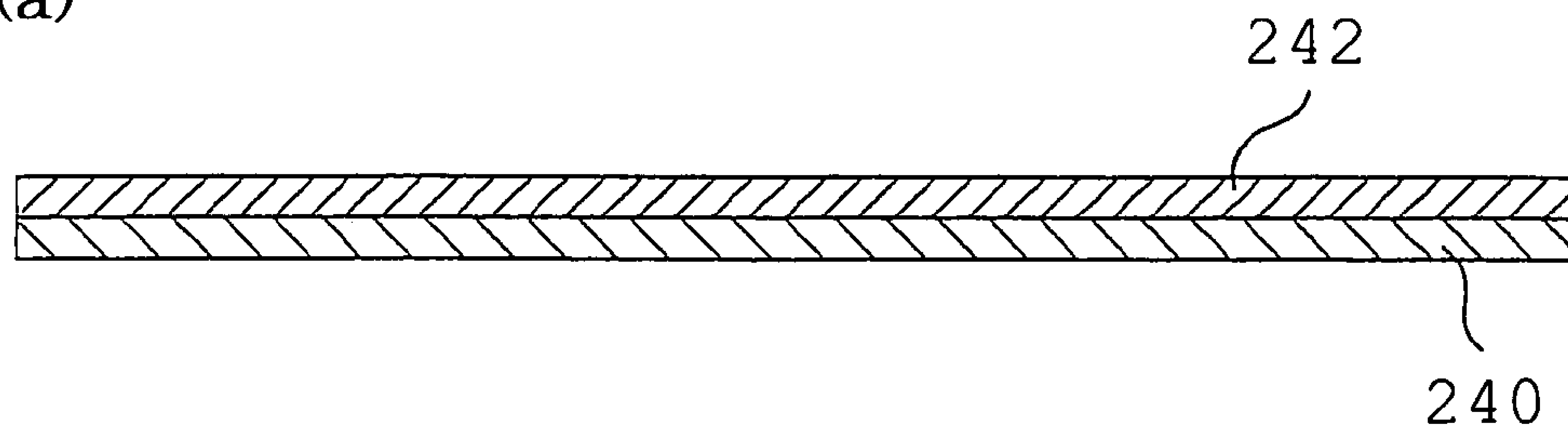


Fig.40(b)

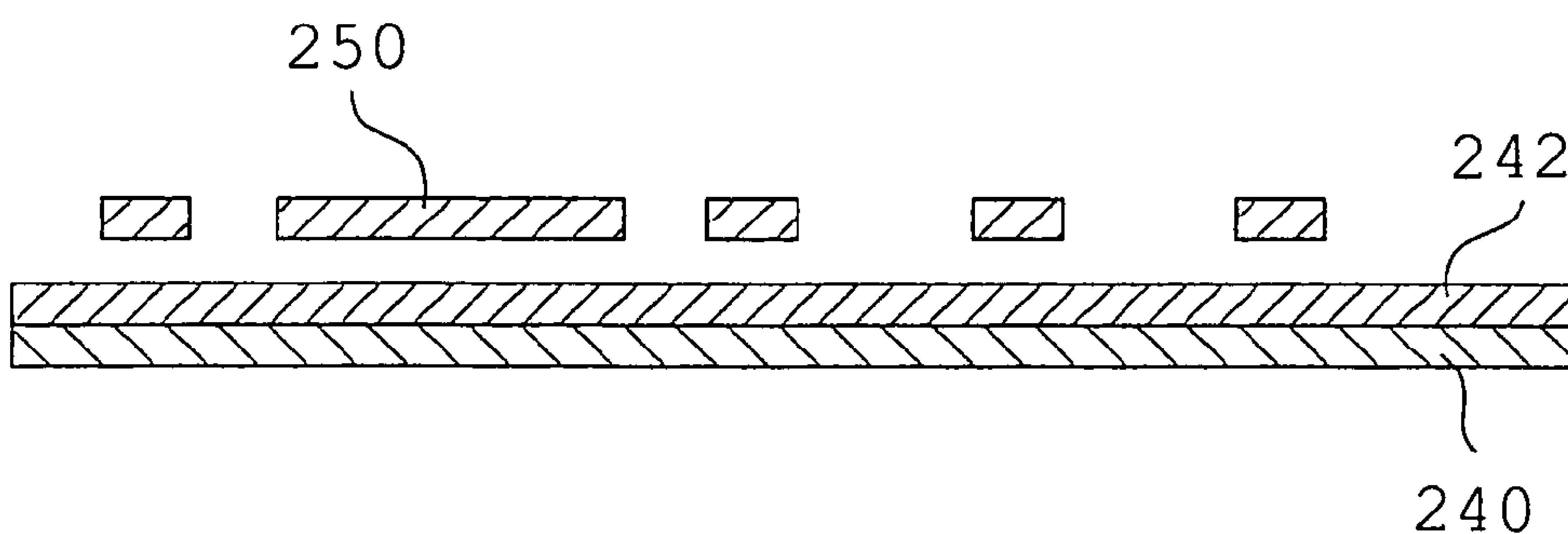


Fig.40(c)

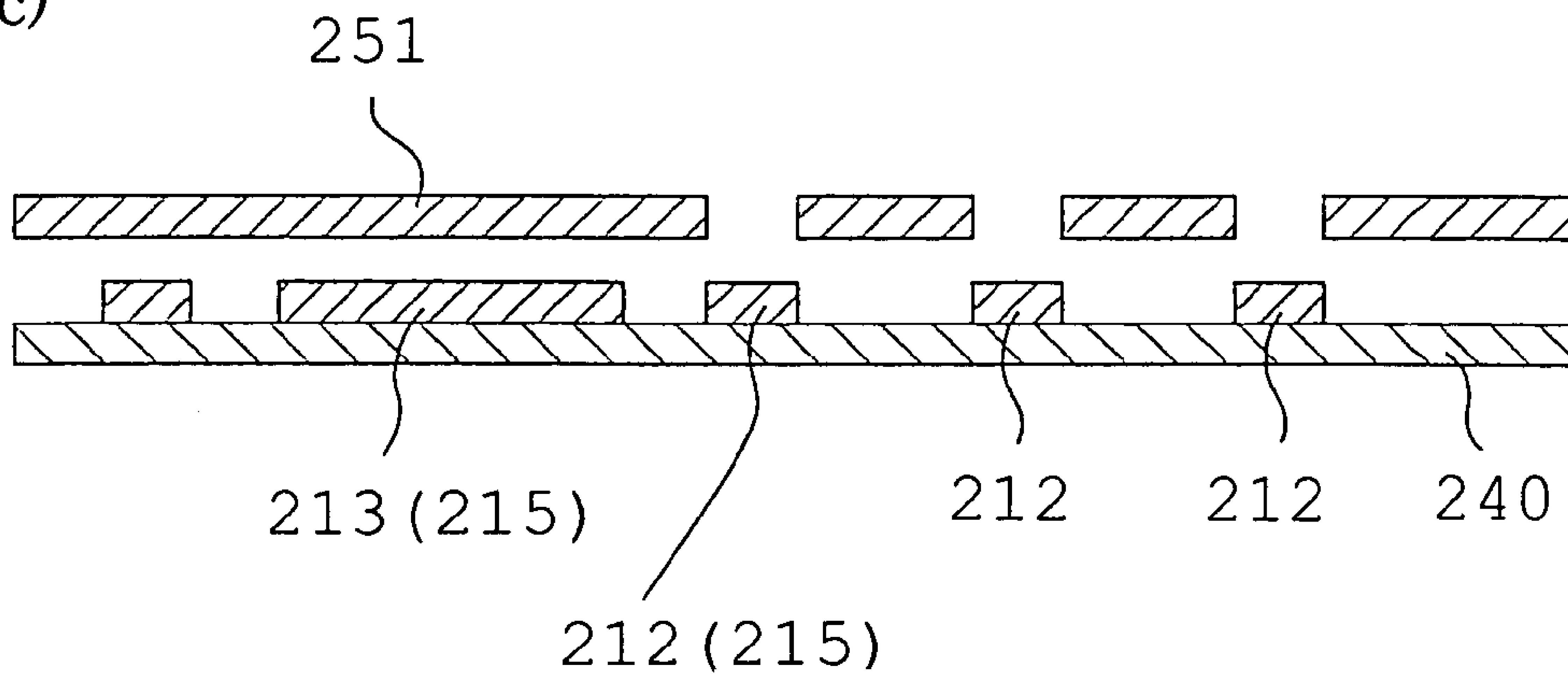


Fig.40(d)

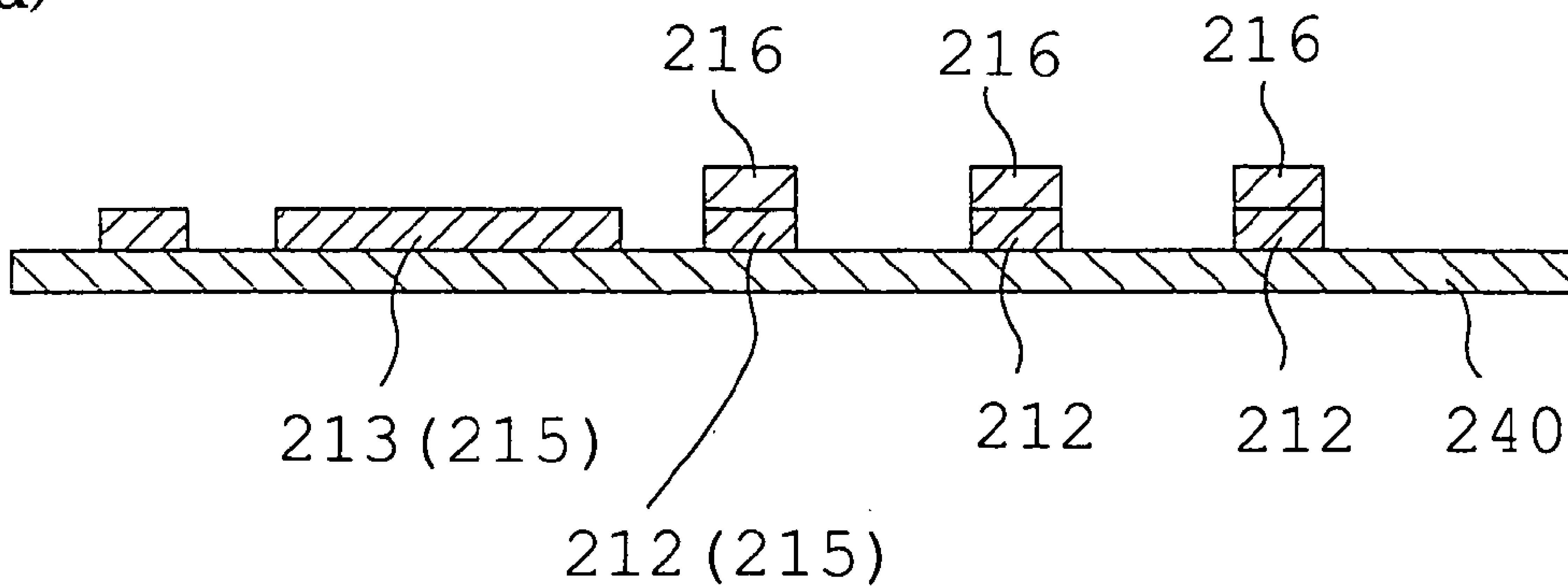


Fig.41(a)

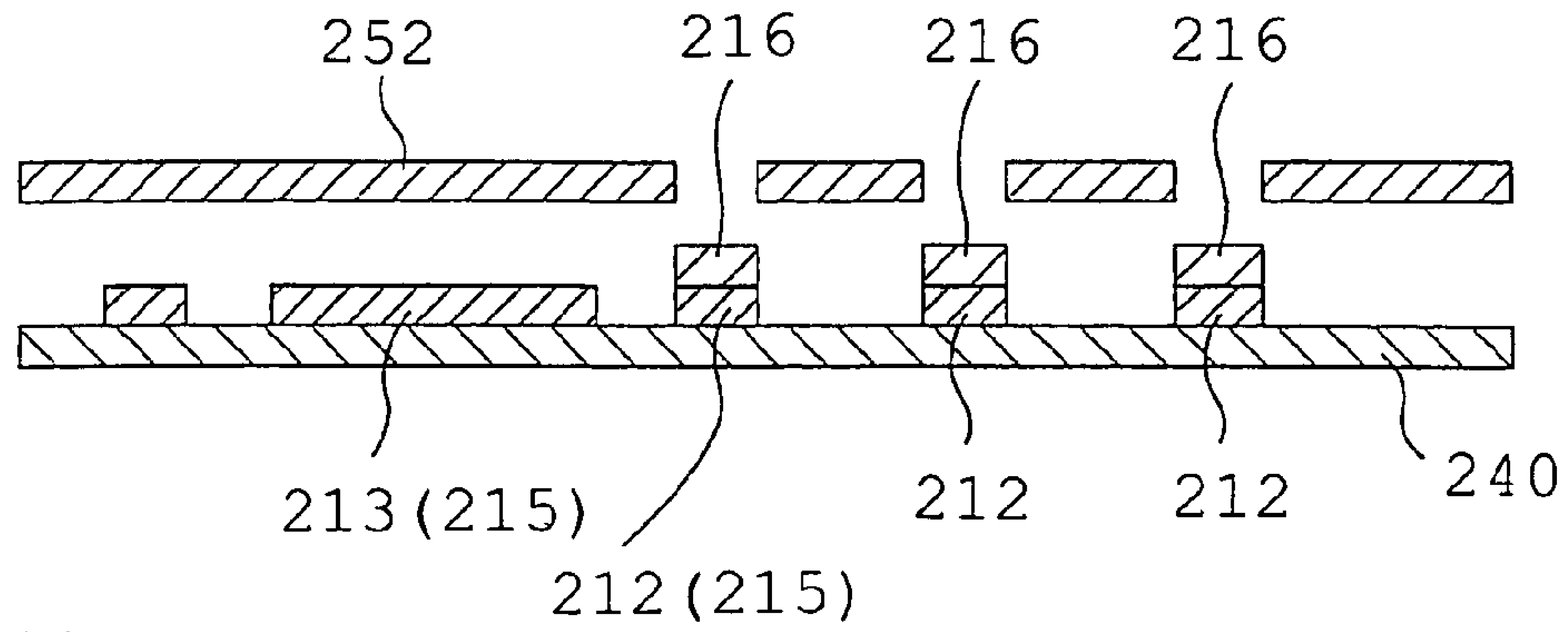


Fig.41(b)

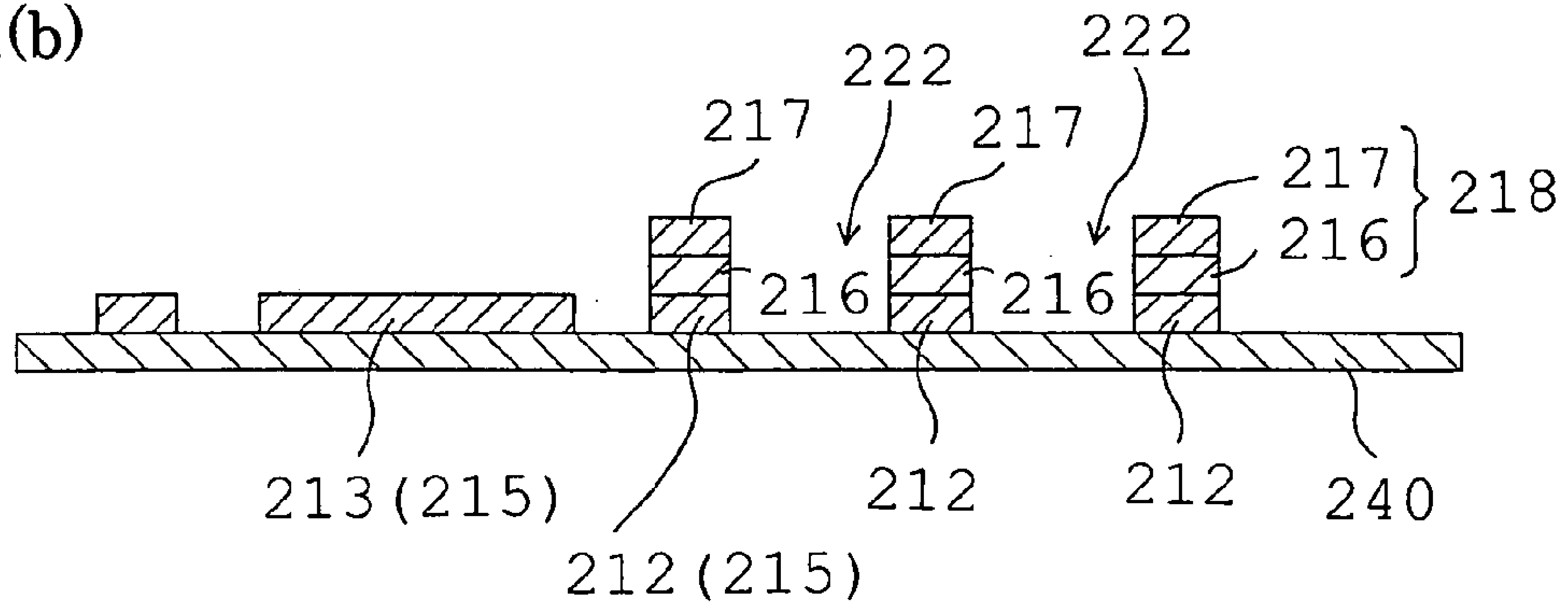


Fig.41(c)

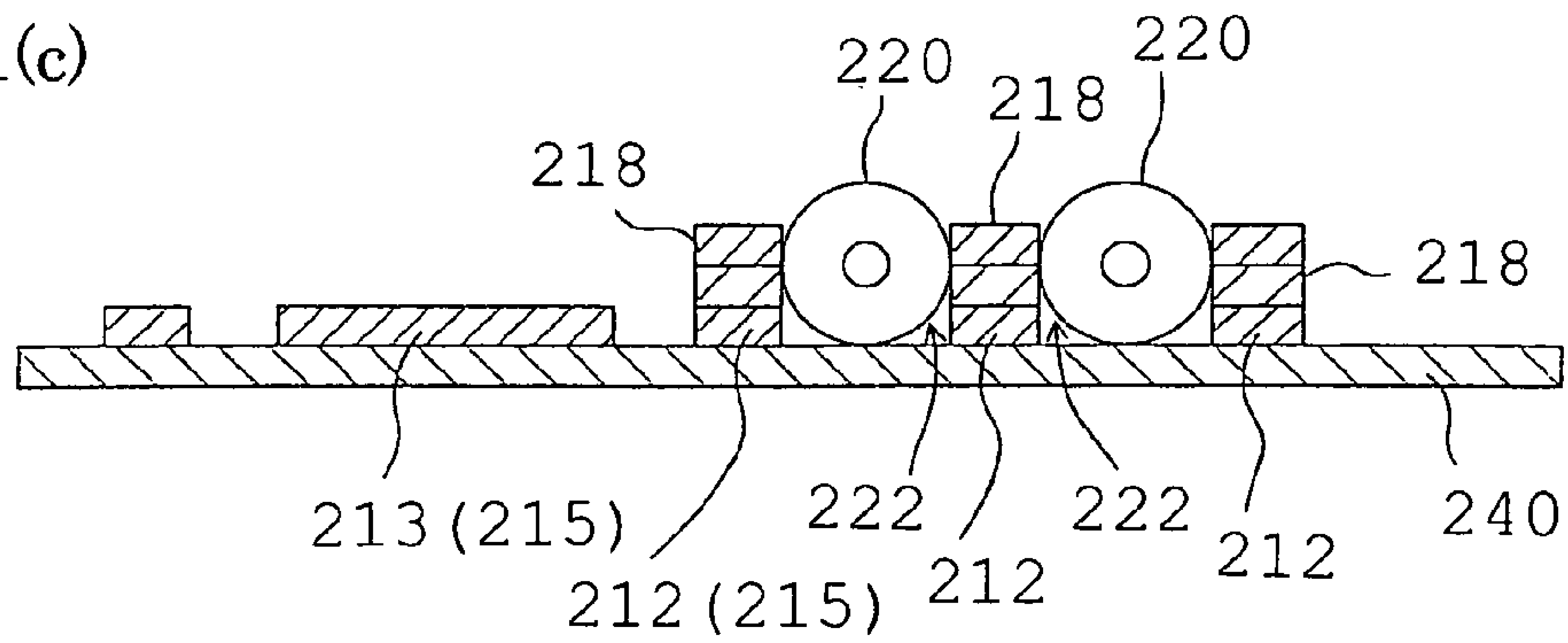


Fig.41(d)

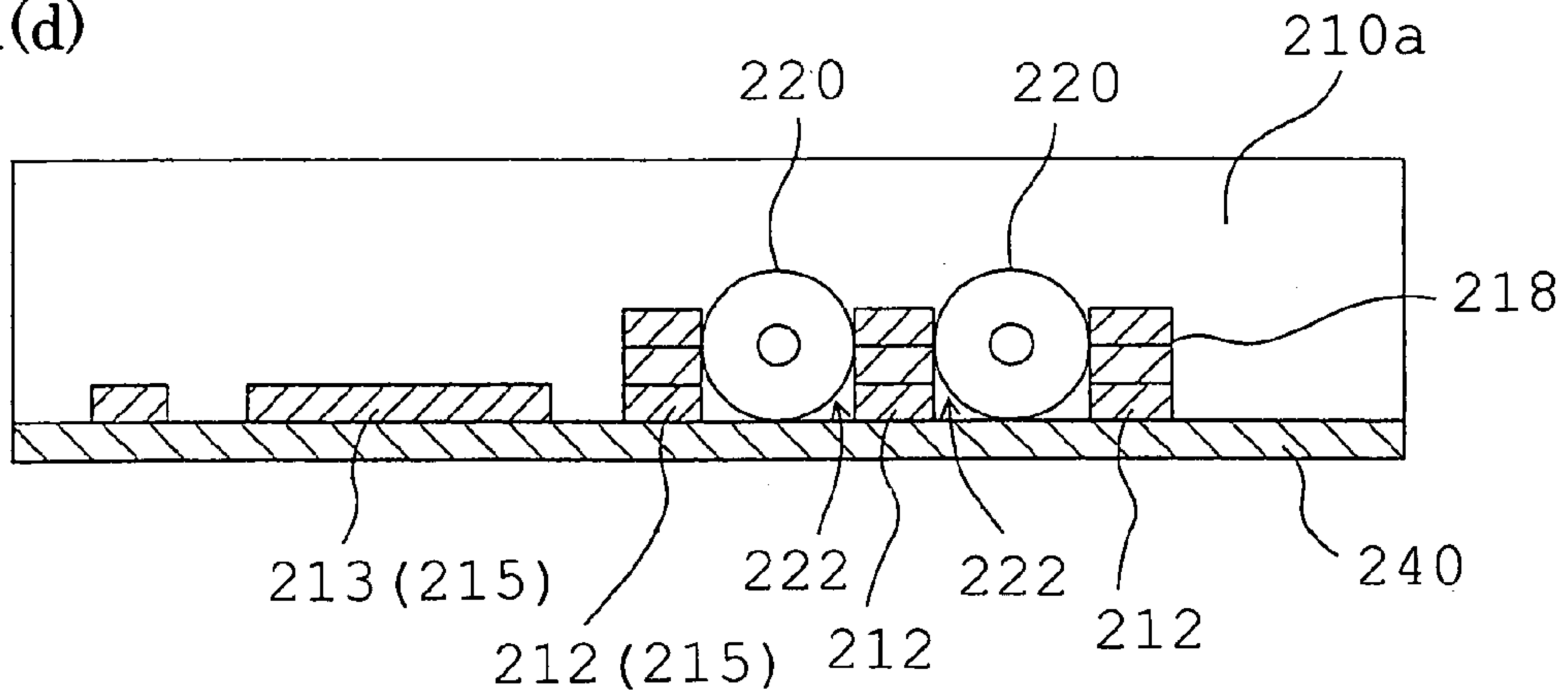


Fig.42(a)

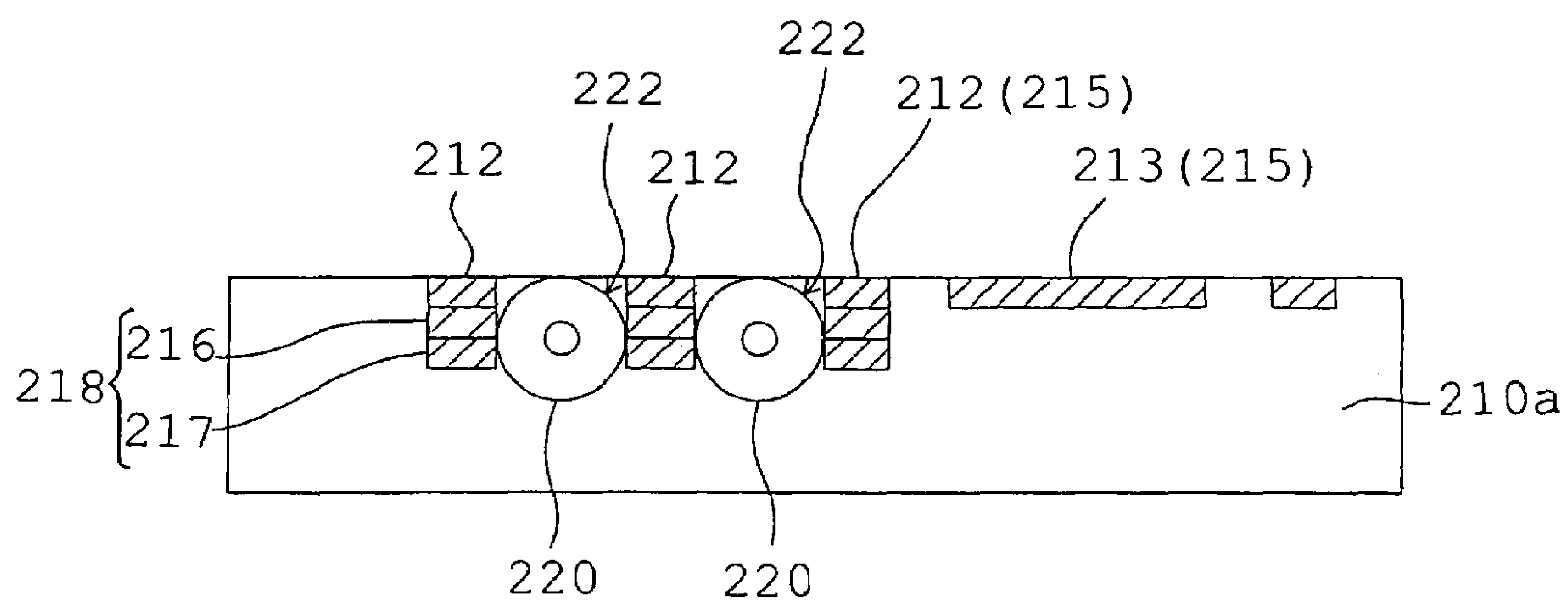


Fig.42(b)

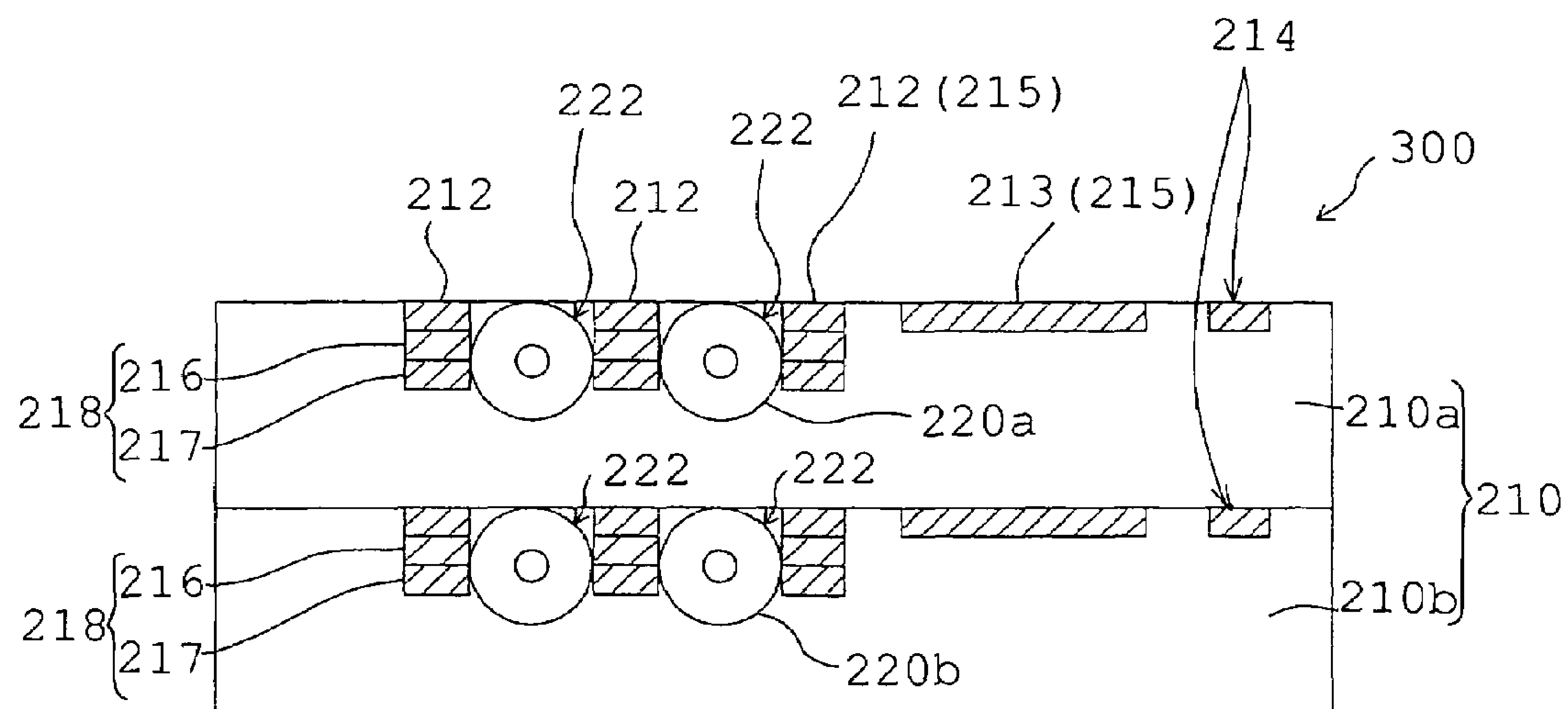


Fig.43

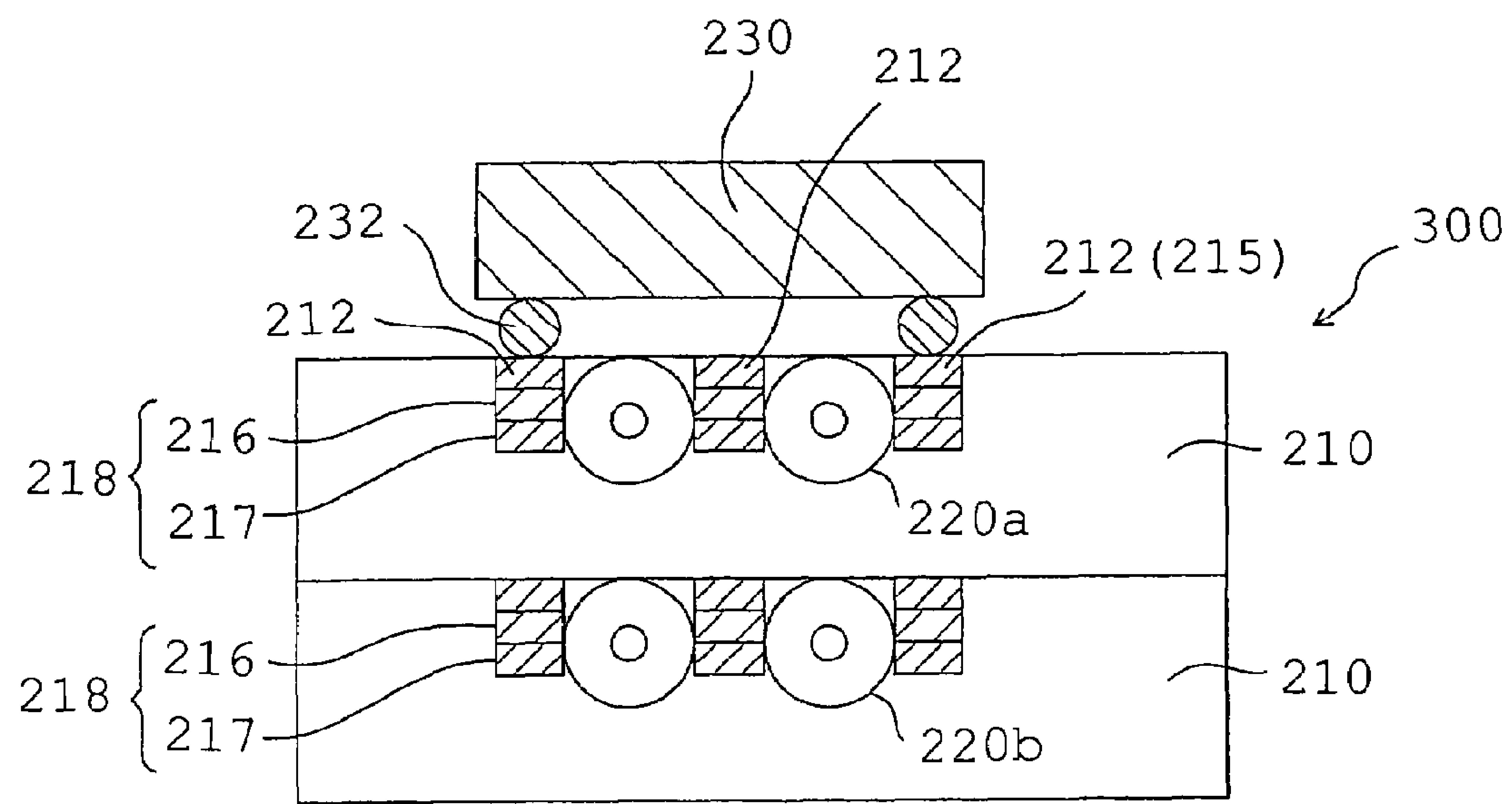


Fig.44

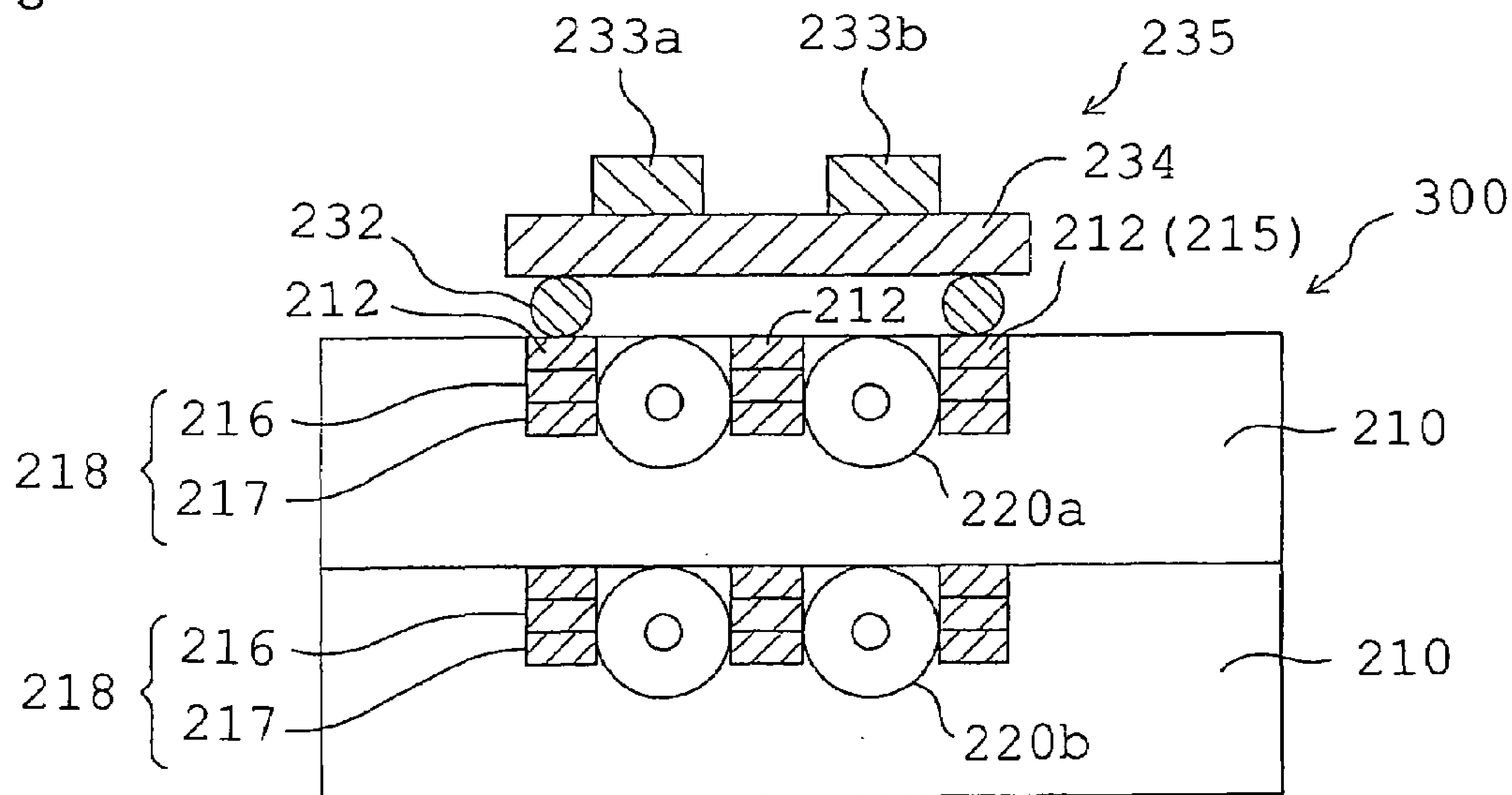


Fig.45(a)

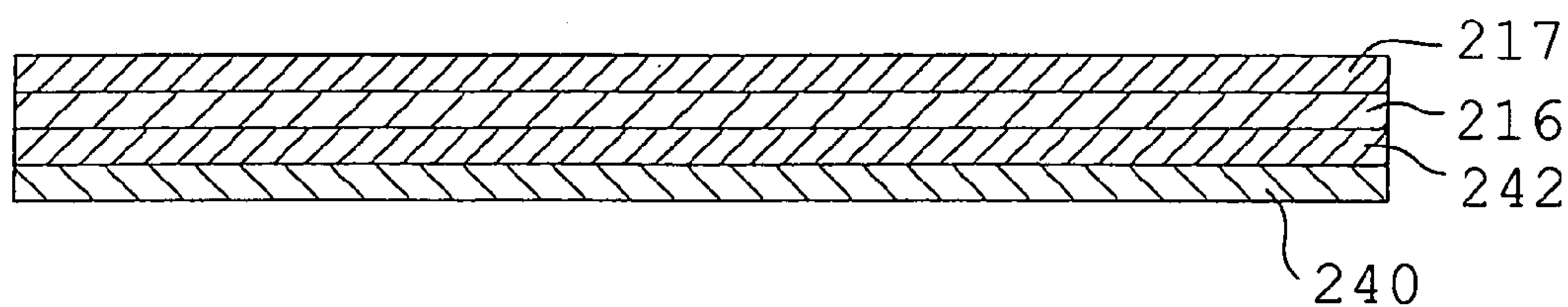


Fig.45(b)

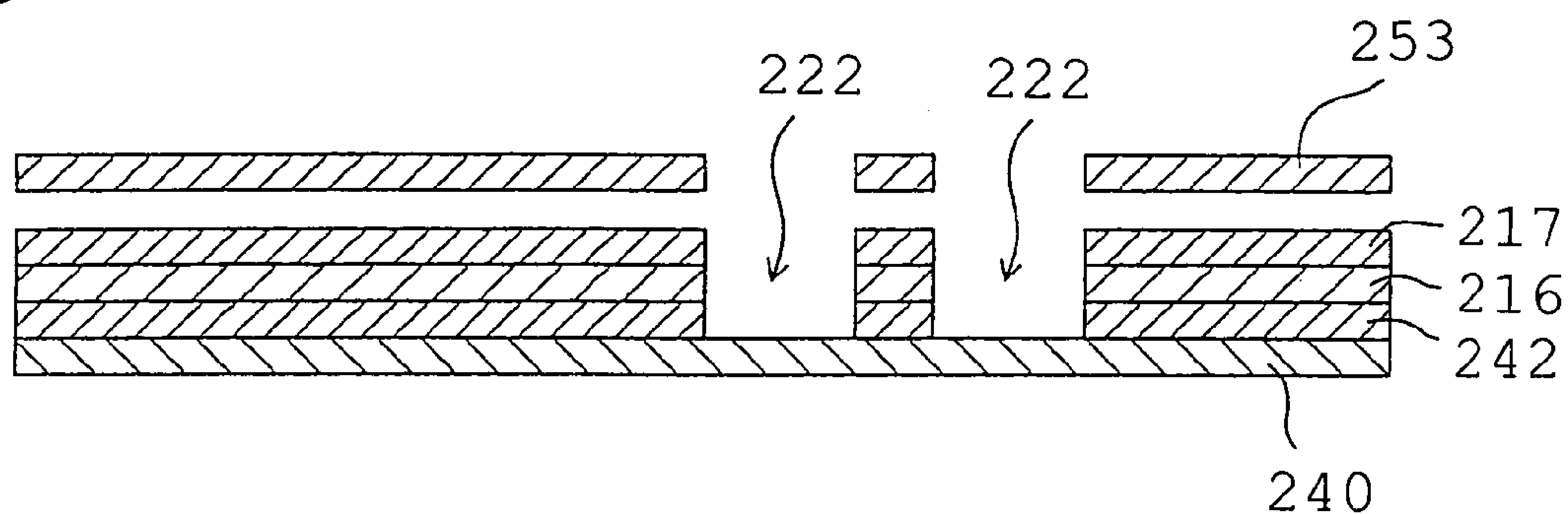


Fig.45(c)

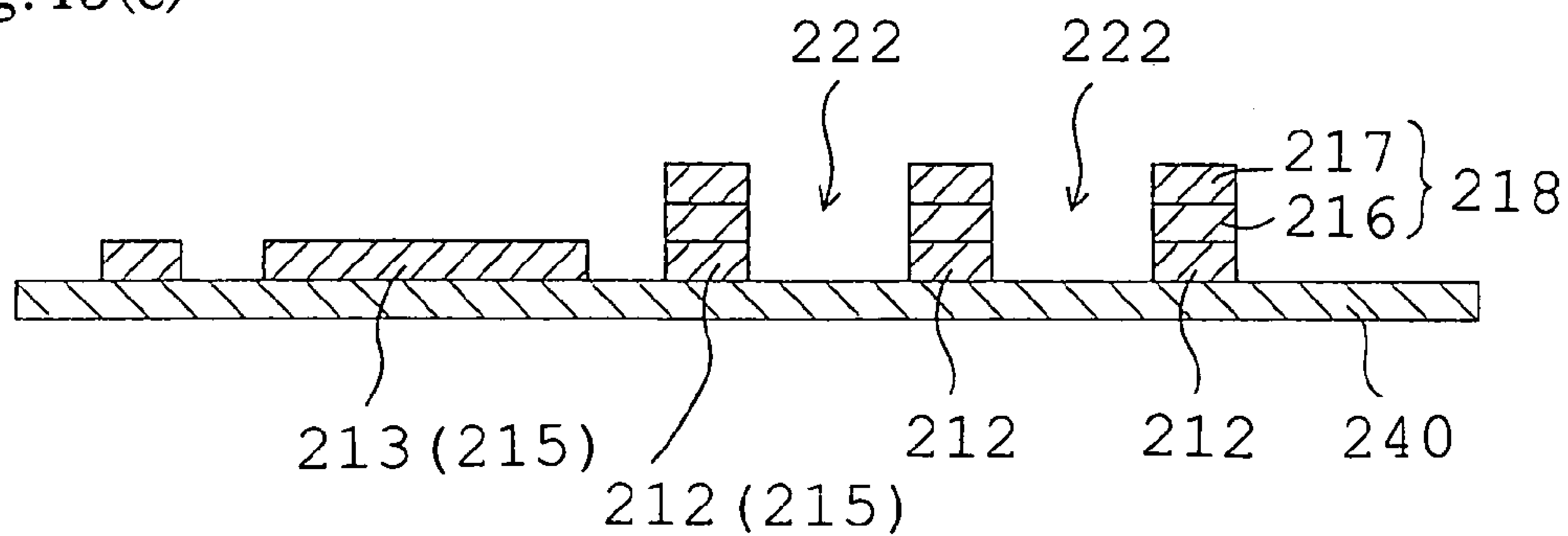


Fig.46

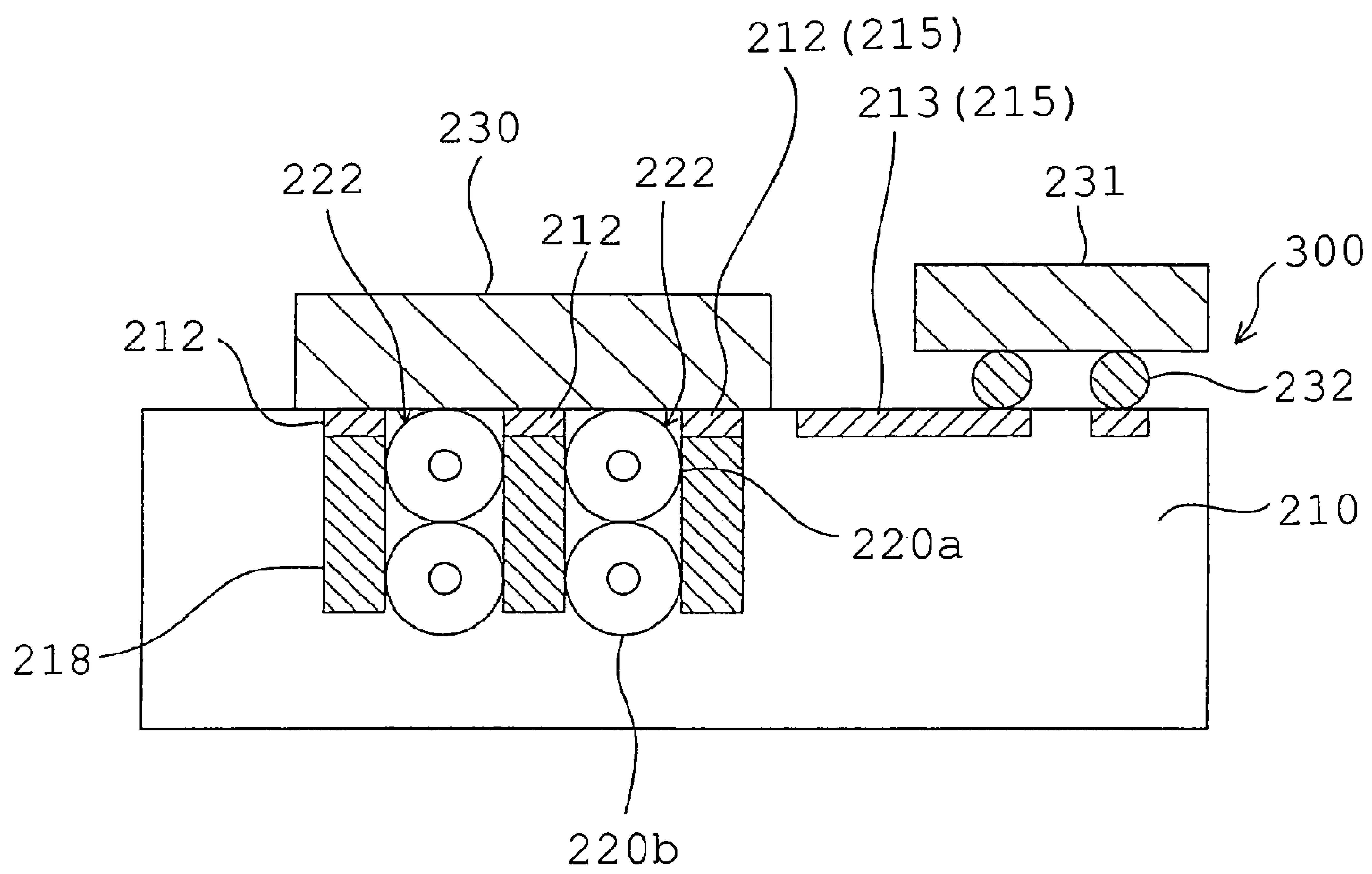


Fig.47

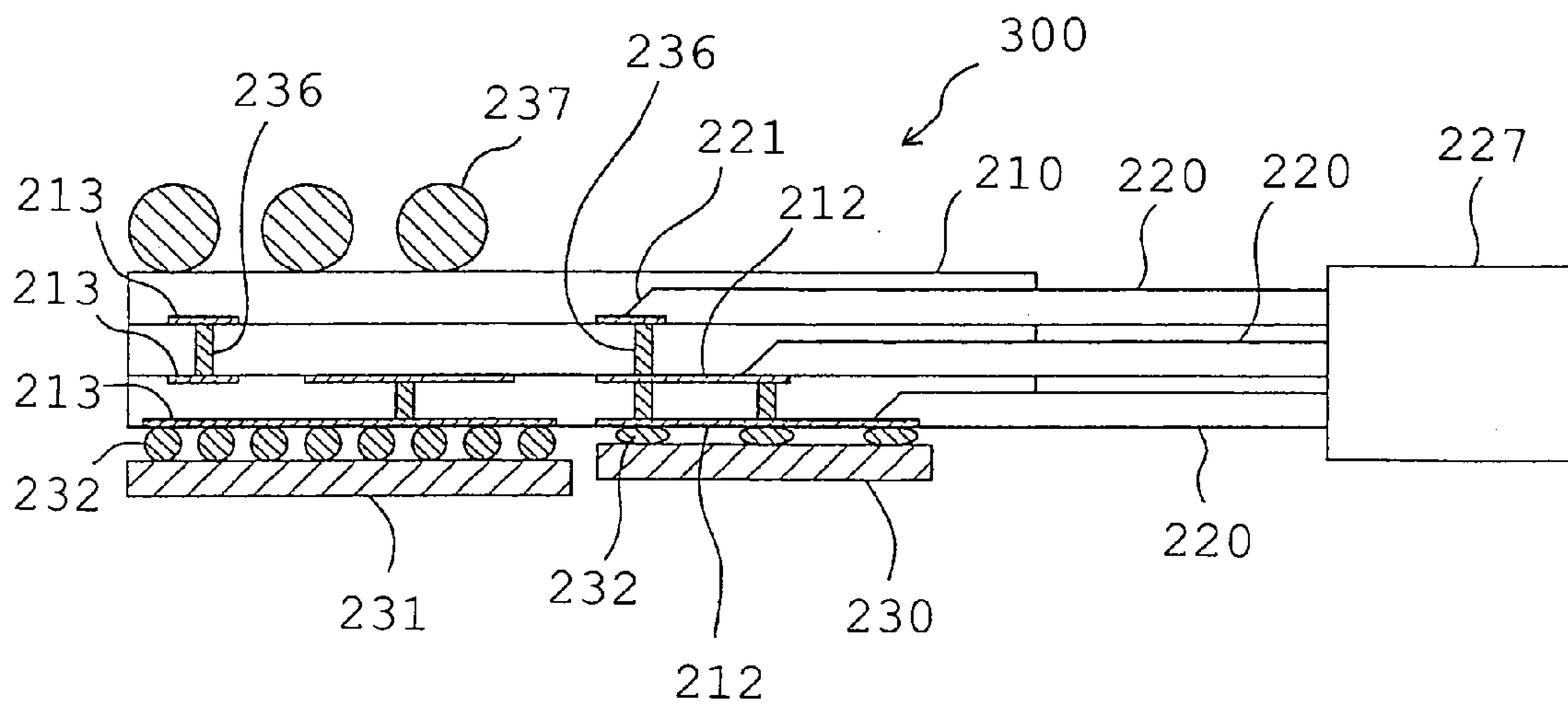


Fig.48

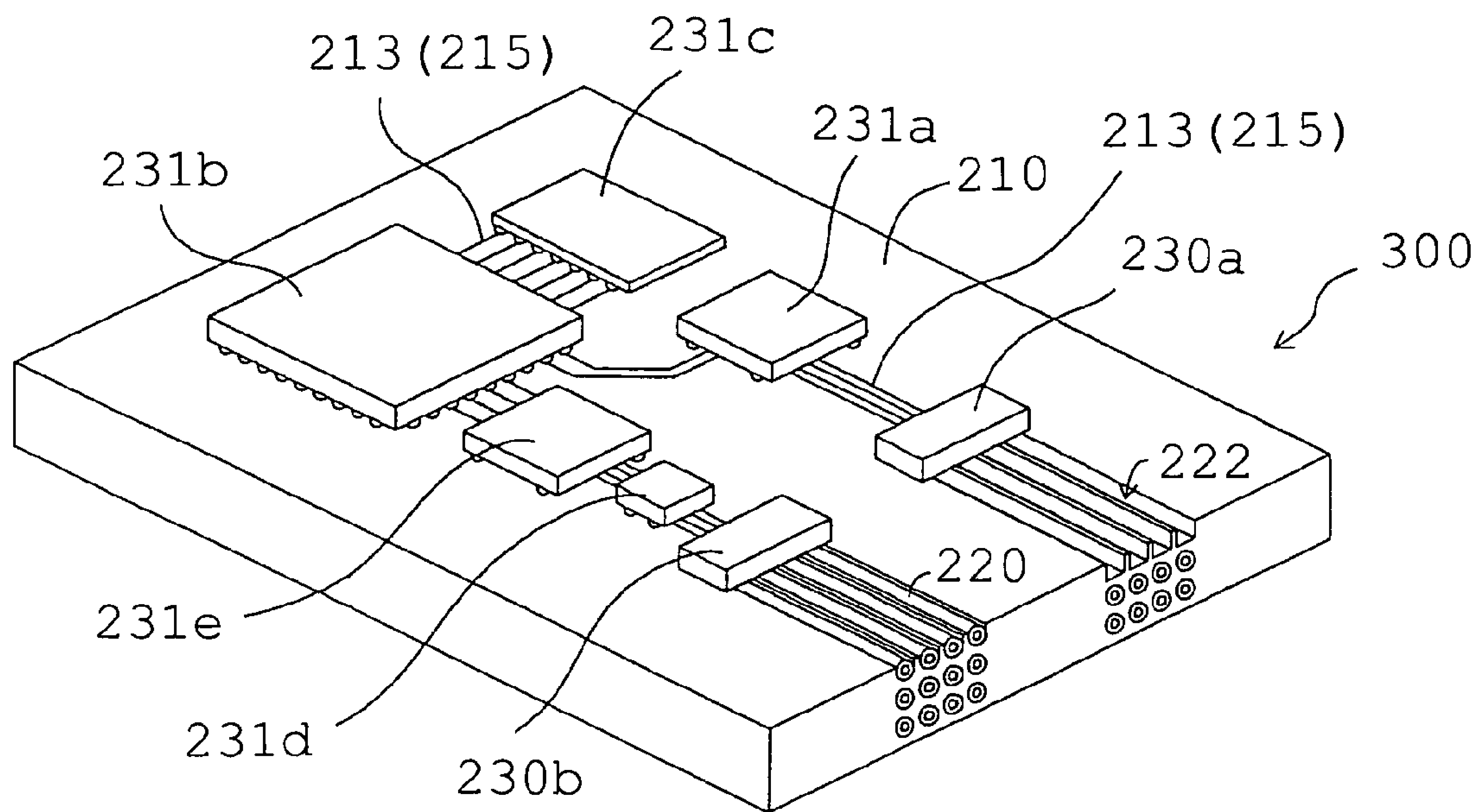


Fig.49

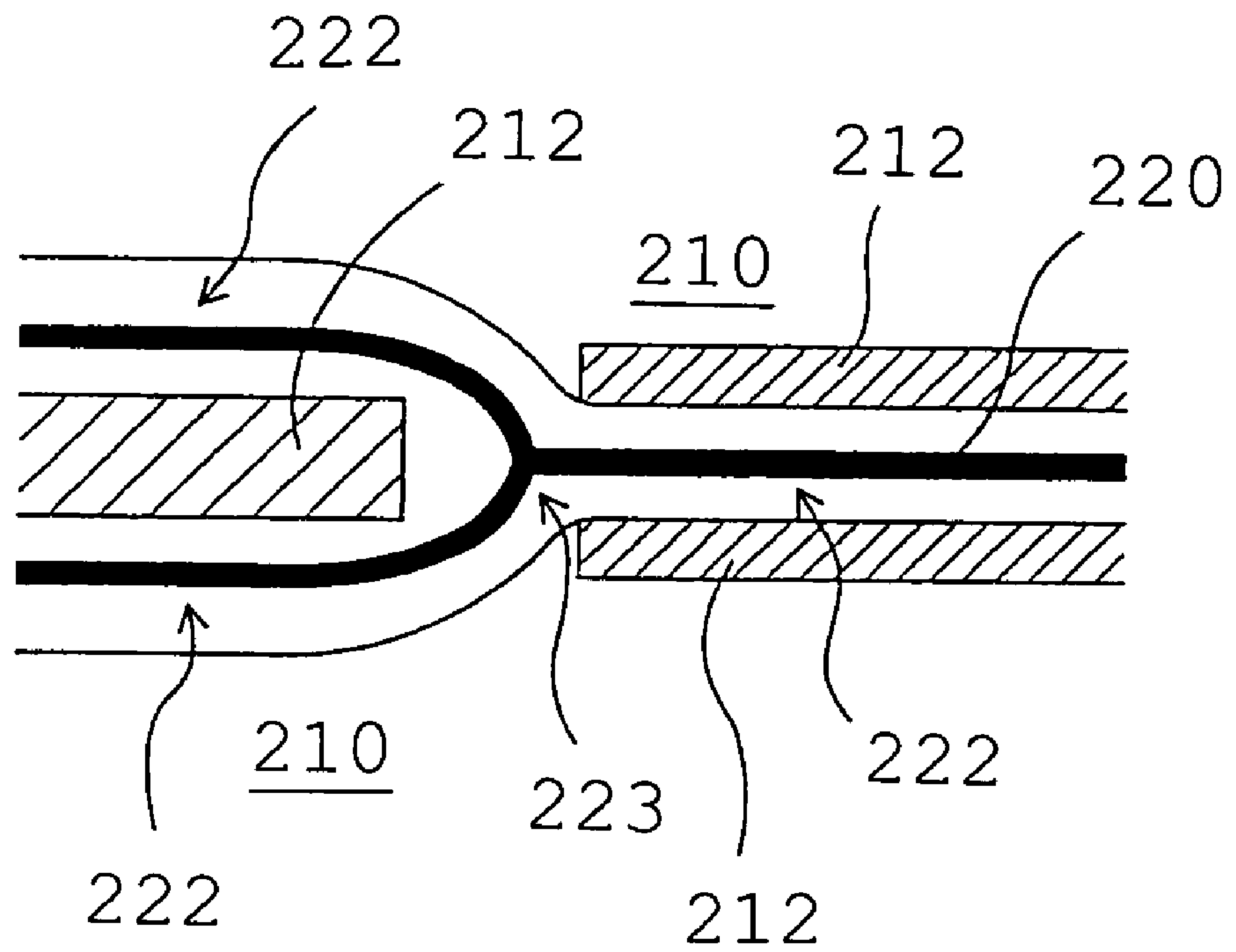


Fig.50 PRIOR ART

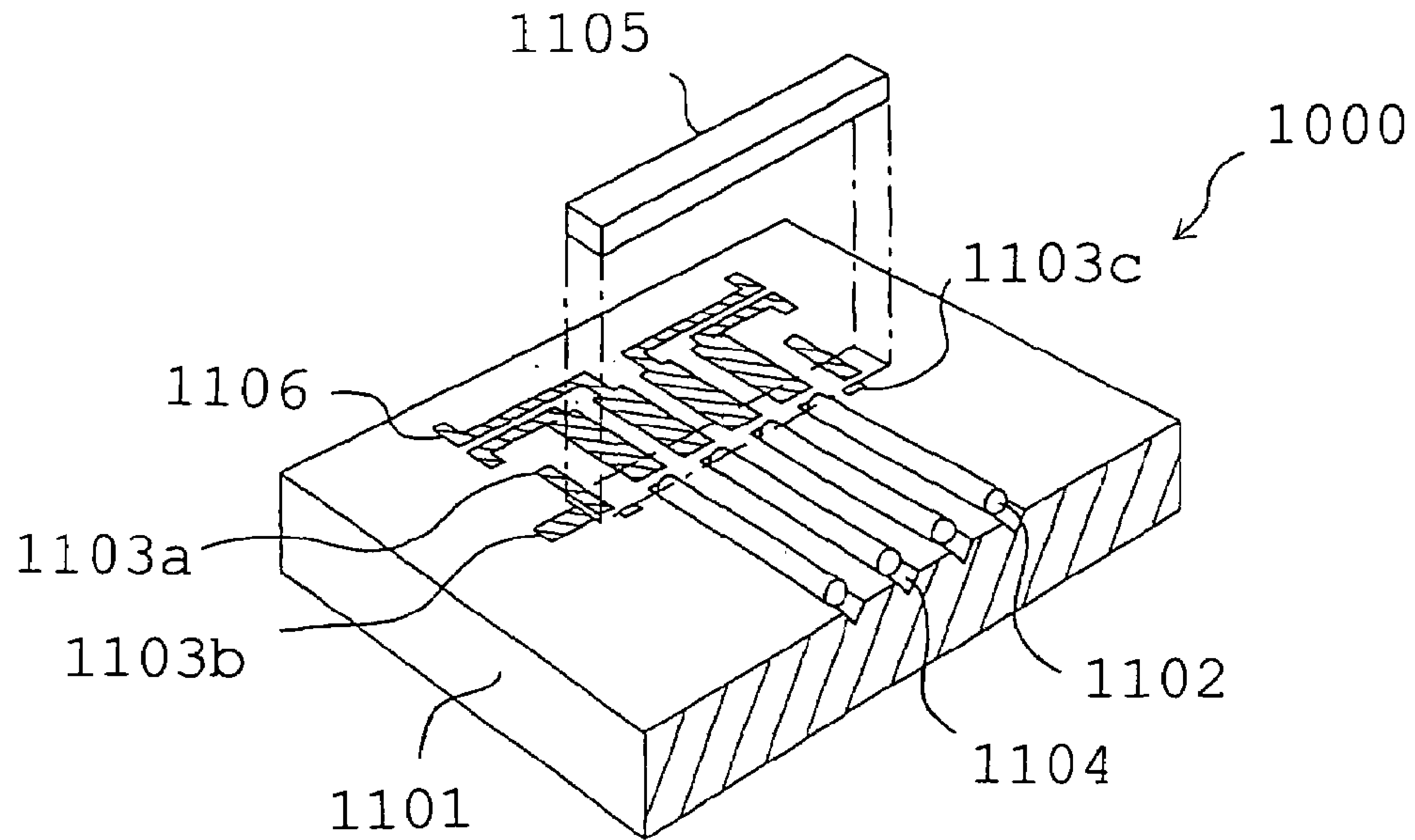


Fig.51 PRIOR ART

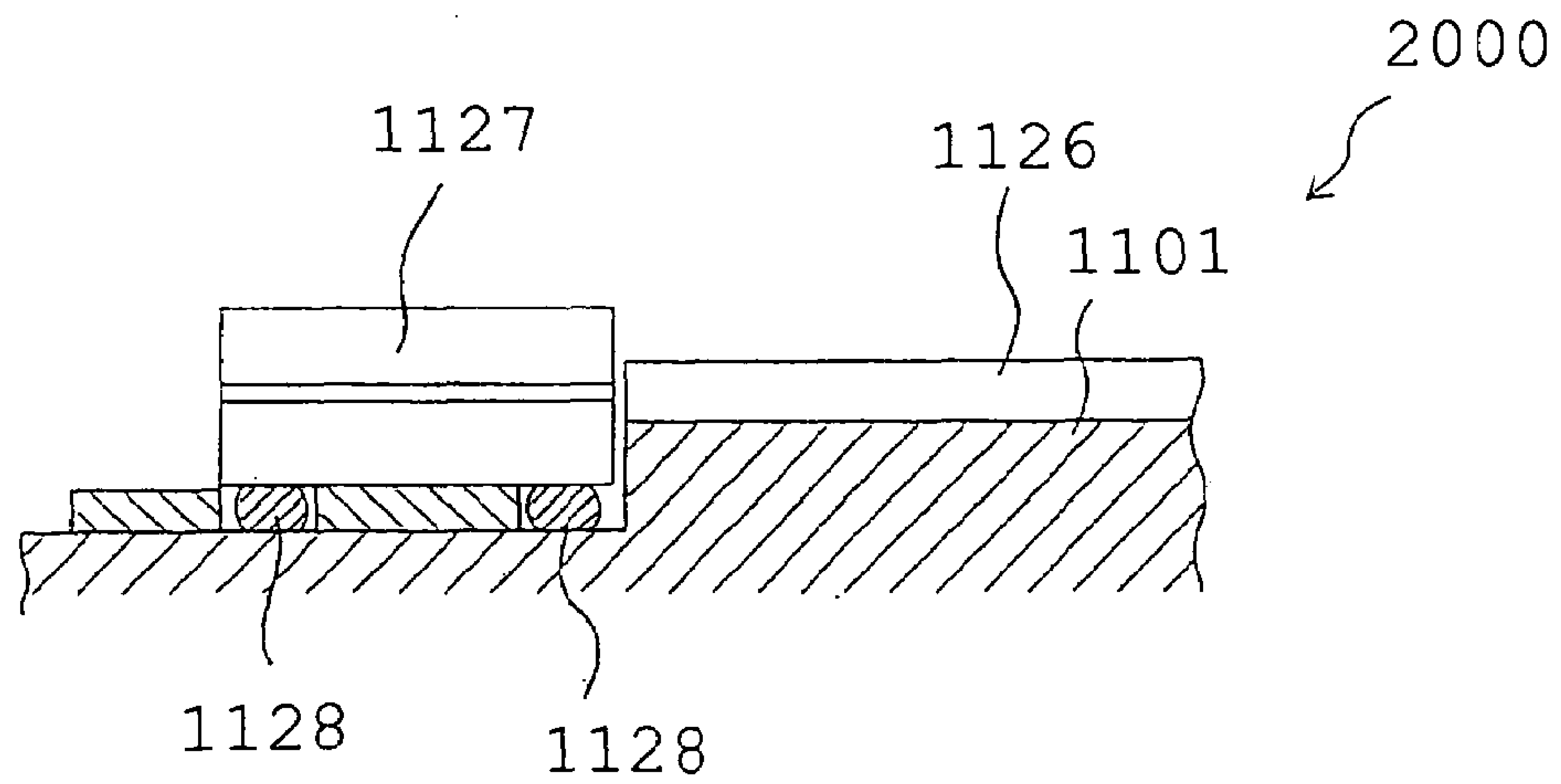


Fig.52 PRIOR ART

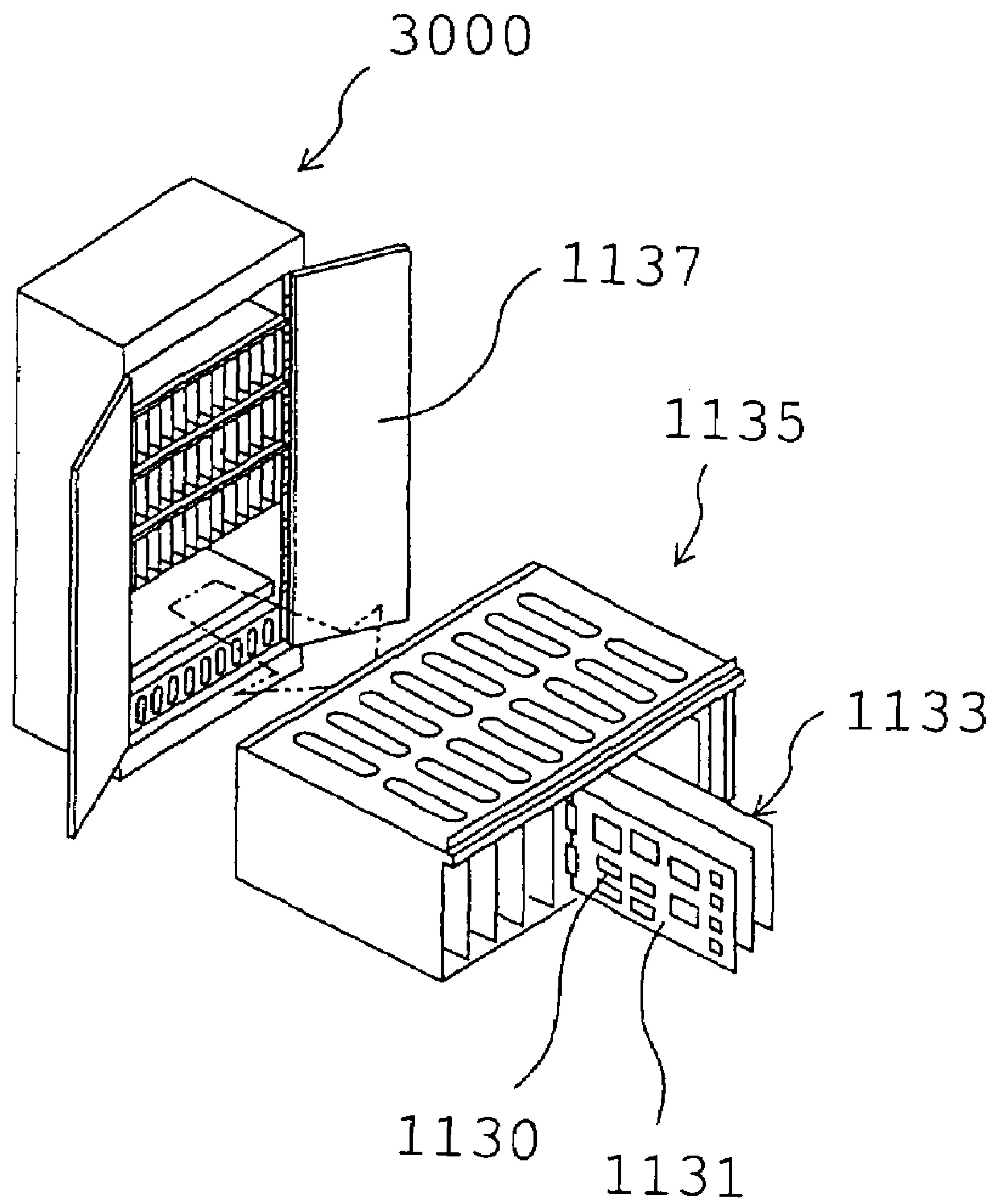


Fig.53 PRIOR ART

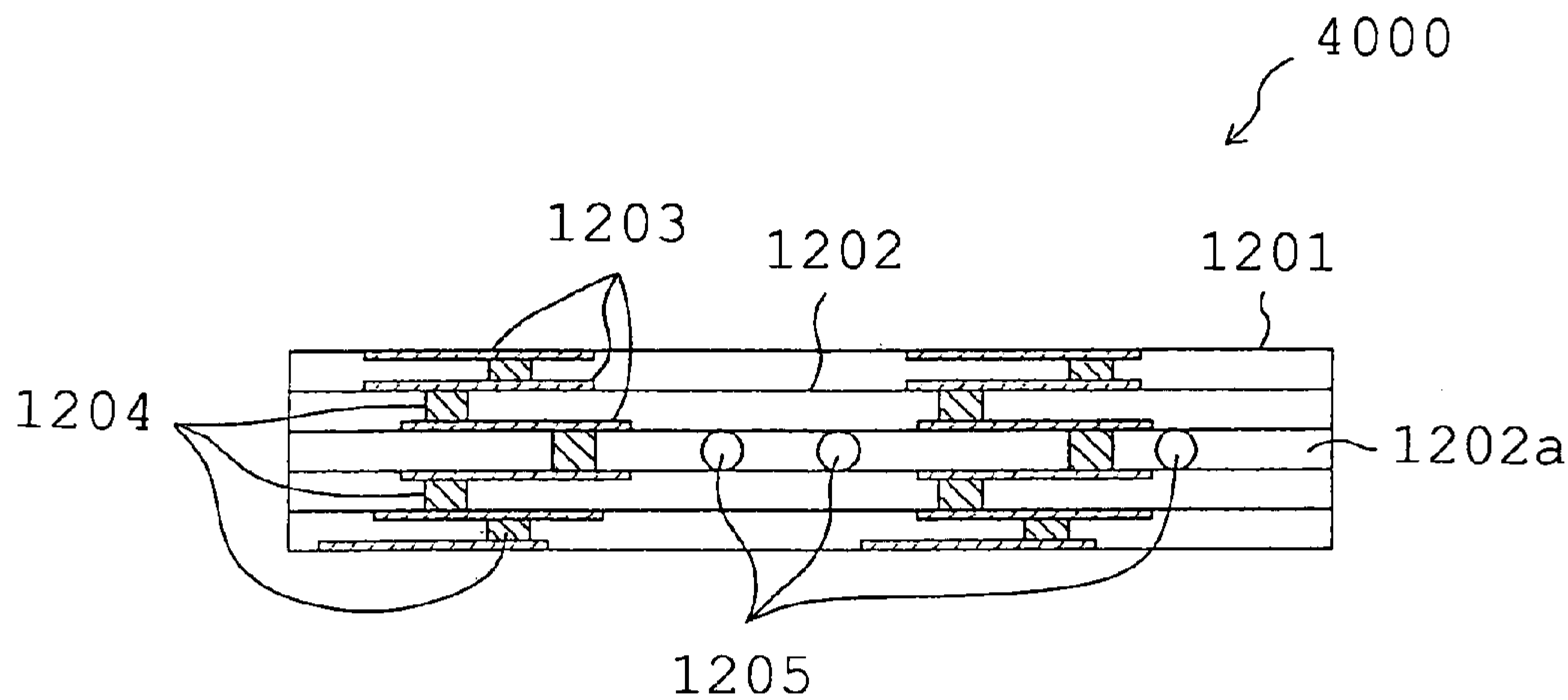


Fig.54(a) PRIOR ART

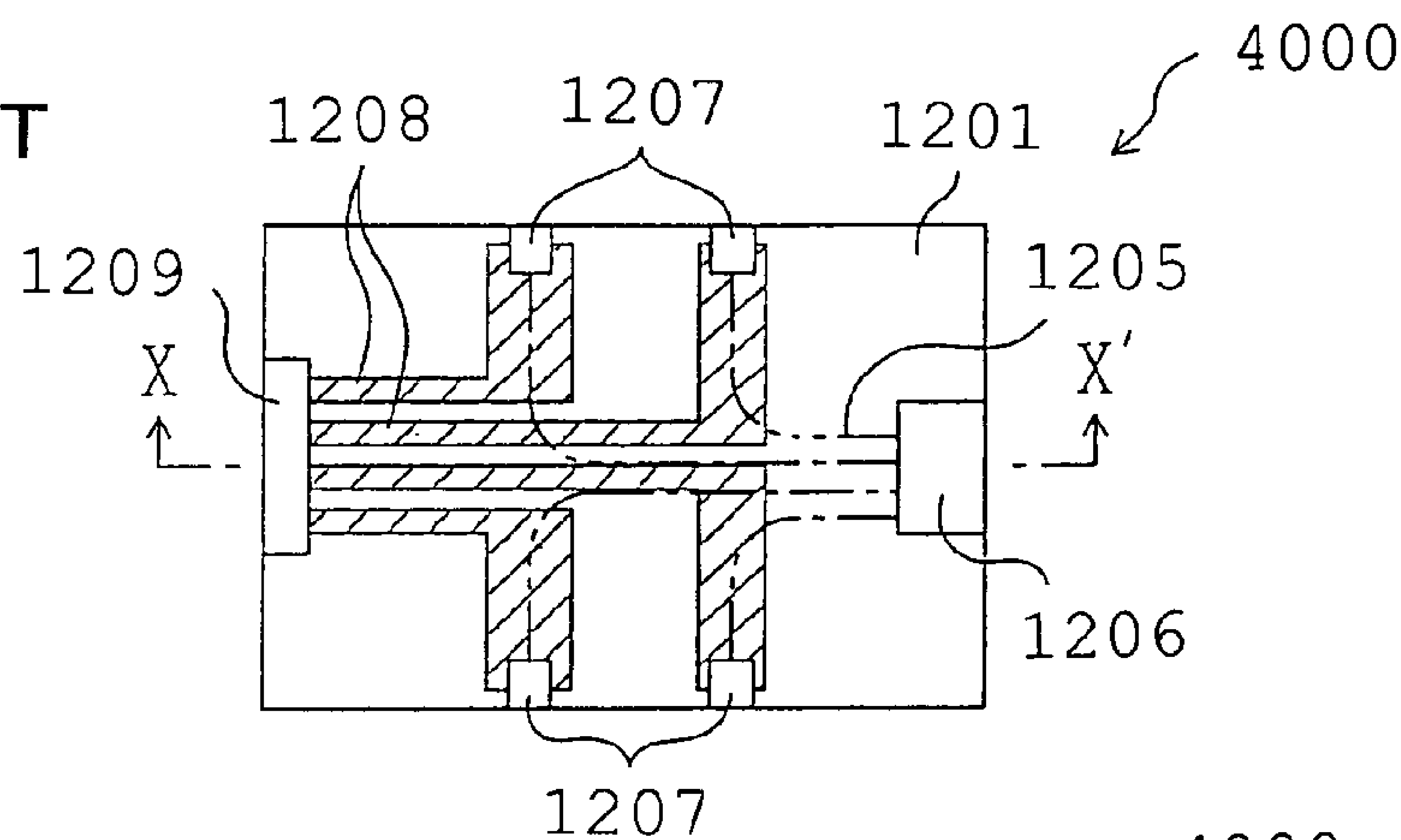


Fig.54(b) PRIOR ART

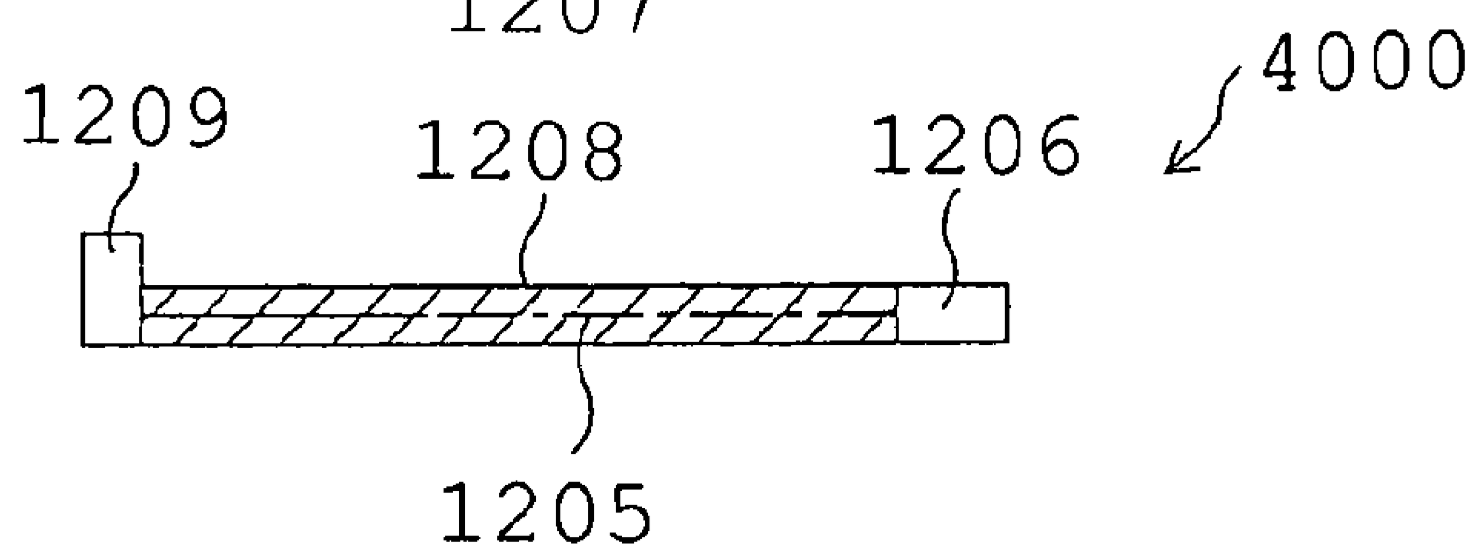
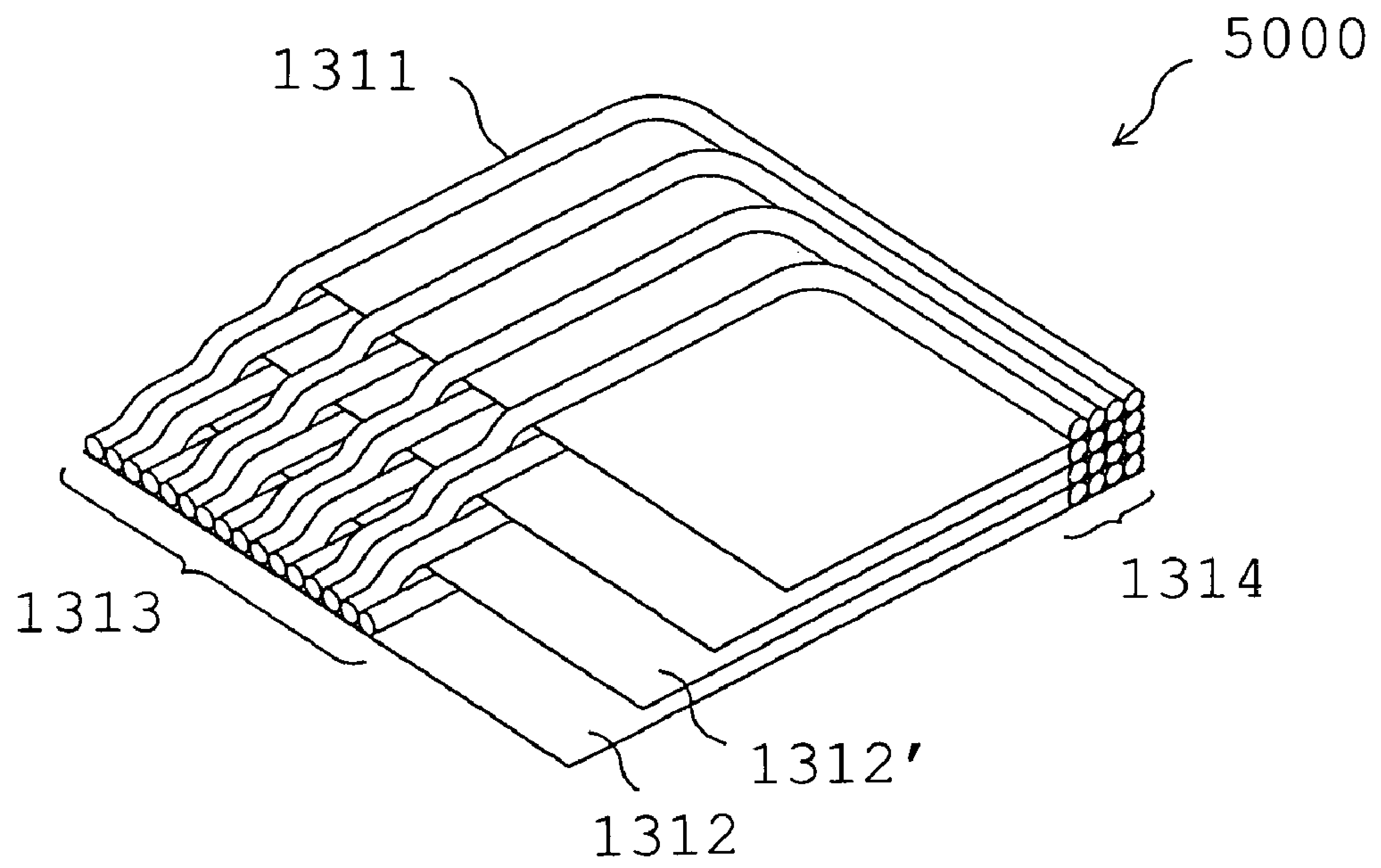


Fig.55 PRIOR ART



OPTICAL TRANSMISSION CHANNEL BOARD, BOARD WITH BUILT-IN OPTICAL TRANSMISSION CHANNEL, AND DATA PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a fabrication method for an optical transmission channel board, an optical transmission channel board, a board with built-in optical transmission channel, a fabrication method for a board with built-in optical transmission channel, and a data processing apparatus.

2. Related Art of the Invention

With recent progress in optical communications and optical information processing, optical circuit mounting technology permitting high-density and economical integration of optical components is increasingly important, and so is the role that optical modules play. An example of a prior art optical module is shown in FIG. **50** (see JP-A-H8-78657).

As shown in FIG. **50**, a prior art optical module **1000** comprises a Si substrate (Si terrace) **1101**, optical fibers **1102**, and a semiconductor laser (optical element) **1105**. Guide grooves (V grooves) **1104** a formed in the Si substrate **1101**. Each optical fiber **1102** is fixed along each guide groove **1104**. Electric wirings **1106** and positioning reference planes (positioning markers) **1103***a*, **1103***b*, and **1103***c* are formed in the Si substrate **1101**. Using these positioning reference planes **1103***a*, **1103***b*, and **1103***c*, the semiconductor laser **1105** is mounted on the Si substrate **1101**, and connected to the electric wirings **1106**. That is, in the optical module **1000**, the optical fibers **1102** and the semiconductor laser (LD) **1105** are integrated on the Si substrate **1101**. This module is driven through the electric wirings **1106**. In the configuration shown in FIG. **50**, the guide grooves **1104** can be fabricated with sufficient accuracy on the basis of the good workability of the Si substrate **1101**. This permits easy integration of the optical fibers **1102** with the optical element such as the semiconductor laser (LD) **1105** and a photo detector (PD).

FIG. **51** shows another optical module **2000** in which an optical waveguide **1126** in place of an optical fiber is formed on a Si substrate **1101** (see JP-A-H8-78657).

In the optical module **2000** shown in FIG. **51**, the optical waveguide **1126** formed on the Si substrate **1101** is optically connected to an opto-semiconductor element **1127** mounted via solder bumps **1128** in a recess formed on the Si substrate **1101**.

The mounting hierarchy in a communication system apparatus **3000** for performing optical communications is described below with reference to FIG. **52**. The communication system apparatus **3000** shown in FIG. **52** is constructed according to a method called bookshelf mounting. This method has an advantage in economical efficiency and packaging density, and hence is used generally.

Further description is given below.

A component of the communication system apparatus **3000** is a semiconductor element (LSI chip) **130**. A plurality of semiconductor elements **130** are used and constitute an MCM (multi-chip module) **1131**. The MCM **1131** is mounted on a board (printed circuit board) **1133**, so that a board assembly is obtained. A plurality of board assemblies are accommodated in a sub-rack **1135**. A plurality of sub-racks **1135** are accommodated in a cabinet **1137**, so that the communication system apparatus **3000** is constructed.

The mounting hierarchy of bookshelf mounting is classified into six levels. That is, level **0** indicates a distance within a chip (~1 mm). Level **1** indicates a distance between chips (~1 cm). Level **2** indicates a distance within a board (~10 cm). Level **3** indicates a distance within a sub-rack (~1 m). Level **4** indicates a distance between sub-racks (~10 m). Level **5** indicates a distance between apparatuses or systems (~100 m) (each quantity between parentheses indicates a transmission distance). Among these levels, in the range of transmission distance exceeding 1 m (level **3**, level **4**, or higher), optical fibers have an advantage as a transmission medium. Thus, the combination of an optical module (such as one shown in FIG. **50**) and an optical fiber is used advantageously. In contrast, transmission within a board (level **2**) is performed generally using a copper circuit pattern on the printed circuit board. That is, such transmission is performed using electricity, not using light.

On the other hand, JP-A-2000-340907 discloses a wiring board (printed circuit board) that has built-in optical fibers. The wiring board disclosed in JP-A-2000-340907 is shown in FIGS. **53**, **54**(*a*), and **54**(*b*).

The wiring board **4000** shown in FIG. **53** comprises an insulating board **1201**. The insulating board **1201** is composed of a plurality of insulating layers **1202**. Wiring circuit layers **1203** are formed on the insulating layers **1202**. Wiring circuit layers **1203** located on different layers are connected through via hole conductors **1204**. Optical waveguide bodies **1205** having a fiber shape (such as optical fibers) are embedded in an insulating layer **1202***a* selected from a plurality of the insulating layers.

As shown in the plan view of FIG. **54**(*a*), the optical waveguide bodies **1205** having a fiber shape are embedded inside an insulating board **1201**, so that an optical waveguide circuit is constructed in which optical signals can be transmitted through these optical waveguide bodies **1205**. FIG. **54**(*b*) is a sectional view taken along line X-X' in FIG. **54**(*a*). The inside of the insulating board **1201** of FIG. **54**(*a*) is illustrated as a schematic diagram for general description purpose, and is not necessarily in agreement with the sectional view of FIG. **53**.

As shown in FIGS. **54**(*a*) and **54**(*b*), an optical connector **1206** is integrally attached to an end of the optical waveguide circuit in one side of the insulating board **1201**. Optical-to-electric signal conversion elements **1207** capable of converting an optical signal into an electric signal is attached in the inside or side portions of the insulating board **1201**. Electric signals converted from the optical signals by the optical-to-electric signal conversion elements **1207** are electrically transferred through the wiring circuit layers **1208** (corresponding to the wiring circuits **1203** shown in FIG. **53**) and the via hole conductors **1204** arranged inside the insulating board **1201**, to an electronic element or the electric connector **1209** mounted on the insulating board **1201**.

JP-A-2000-66034 discloses an optical wiring board permitting the wiring of a large number of optical fibers.

The optical wiring board disclosed in JP-A-2000-66034 is shown in FIG. **55**. In the optical wiring board **5000** of FIG. **55**, one or two or more optical fibers **1311** are mounted on the board using the technique of a picture drawn with a single stroke of a pencil. In the optical wiring board **5000**, the optical fibers **1311** are stacked in a certain part.

The optical wiring board **5000** shown in the figure has a four-layer structure. The optical fibers **1311** are arranged on boards **1312** and **1312'**. End portions **1313** of the optical fibers **1311** are arranged in line on the same plane, while end portions **1314** are multi-layered.

When an optical module such as the optical module **1000** shown in FIG. **50** is to be fabricated, in a prior art fabrication method, the electric wirings **1106** are fabricated on the board **1101** by etching or the like, and then the guide grooves **1104** are fabricated by machining or the like. As such, the fabrication processes for the electric wirings **1106** and for the guide grooves **1104** are completely separated. This has caused complicated fabrication processes, and hence caused an increase in time and cost.

Further, at a glance of the optical module **1000** of FIG. **50**, the module might seem to be fabricated easily. Nevertheless, in practice, centering is necessary between each of the optical fibers **1102** and the optical element **1105**. This centering process is notably complicated. The "centering" described here indicates the process of aligning the optical axes of each optical transmission channel (optical fiber) and the optical element (such as semiconductor laser).

For example, when the optical fibers **1102** are single-mode fibers, only a discrepancy in the submicron order is allowable between each optical fiber **1102** and the optical element **1105**. Nevertheless, considering the deviation (tolerance) occurring in the fabrication of the guide grooves (V grooves) **104** in the Si substrate **101** and the deviation (tolerance) occurring in the fabrication of the optical element positioning reference planes **1103***a*, **1103***b*, and **1103***c* formed together with the electric wirings **1106**, it is concluded that the mounting of the optical element **1105** merely based on the alignment with the optical element positioning reference planes **1103***a*, **1103***b*, and **1103***c* is insufficient because the discrepancy can exceed the tolerance between each optical fiber **1102** and the optical element **1105**. Thus, the centering is unavoidable.

Also in the configuration of FIG. **51**, electric wirings (not shown) located under the solder bumps **1128** are fabricated in a separate process from that for the optical waveguide **1126**. Thus, a similar problem a rises concerning the discrepancy between the optical fiber **1102** and the optical element **1105**.

Even if the problem of discrepancy between the optical fiber **1102** and the optical element **1105** could not arise in the optical module **2000** shown in FIG. **51**, a higher cost is caused in the fabrication of the optical waveguide **1126** on the Si substrate **1101** in comparison with the case that an optical fiber **1102** is used. Thus, another problem arises concerning economical efficiency.

From the perspective of economical efficiency, the use of copper circuit patterns of a printed circuit board is advantageous, for example, in the within-the-board transmission (level **2**) in the communication system apparatus **3000** shown in FIG. **52**. Nevertheless, this causes a problem that the upper limit is reduced in the transmission speed. This is because despite that GHz-level transmission is achieved in optical interconnection, merely MHz-level transmission is achieved in electric interconnection.

Further, in the wiring board **4000** shown in FIGS. **53** and **54**, centering is necessary between each optical waveguide body **1205** embedded in the insulating board **1201** and each optical-to-electric signal conversion element **1207**. This centering process is complicated, and hence increases the cost.

Furthermore, in the within-the-board transmission in the communication system apparatus **3000** shown in FIG. **52**, if the electric interconnection were replaced with optical interconnection in order that the problem of transmission speed could be resolved, an unacceptably large number of optical fibers or optical waveguides would need to be arranged on the board. Thus, another problem would arise concerning the actual device structure. More specifically, the board surface would be filled with optical fibers or the like. This causes a difficulty in the handling, as well as an increase in the board size and in the rate of failure such as disconnection in the optical fibers or the like.

Thus, in order that a large number of optical fibers or optical transmission channels should be arranged with in a limited region, the optical fibers or the optical transmission channels could be constructed in multi-stage. Nevertheless, the method for this multi-stage construction is a difficult problem to be devised in the case of the actual configuration of the optical modules **1000** and **2000** shown in FIGS. **50** and **51**. A new way of thinking is necessary for solving this problem. That is, in the optical module **1000** shown in FIG. **50**, the guide grooves (V grooves) **1104** are formed in the Si substrate **1101** so that the optical fibers **1102** are fixed in the guide grooves **1104**. Thus, the configuration of single-stage arrangement is unavoidable in principle. On the other hand, in the optical module **2000** shown in FIG. **51**, the optical waveguide **1126** is formed on the Si substrate **1101**. Thus, similarly, the configuration of single-stage arrangement is unavoidable in principle.

Further, the wiring board **4000** shown in FIGS. **53** and **54** is disclosed in the case that a single insulating layer **1202***a* is used and that the optical waveguide bodies **1205** are embedded therein. In contrast, if a plurality of such layers were to be provided in the configuration, a new problem would arise in the method of attaching the optical-to-electric signal conversion elements **1207**. In addition, JP-A-2000-340907 does not disclose the case that the optical waveguide bodies **1205** presently embedded in the insulating board **1201** are arranged in a different hierarchy from that of the optical-to-electric signal conversion elements **1207**. Accordingly, no disclosure or indication is provided concerning the method for precisely adjusting their positions for their optical connection. Further, although the optical wiring board **5000** shown in FIG. **55** is a board with built-in optical fibers, no disclosure or indication is provided concerning the configuration that optical-to-electric signal conversion elements **1207** are attached directly to all the optical fibers of the optical wiring board **5000**. Thus, it should be notably difficult to precisely adjust the positions for optical connection.

With considering the above-mentioned problems in the prior art, a purpose of the present invention is to provide: a fabrication method for an optical transmission channel board which can be fabricated in a simpler fabrication process; such an optical transmission channel board; and a data processing apparatus employing this optical transmission channel board. Another purpose of the present invention is to provide a fabrication method for an optical transmission channel board which needs no centering process or merely a simpler centering process; such an optical transmission channel board; and a data processing apparatus employing this optical transmission channel board.

Yet another purpose of the present invention is to provide a fabrication method for an optical transmission channel board which can be fabricated at a lower cost.

Another purpose of the present invention is to provide a board with built-in optical transmission channel on which an optical element (such as a semiconductor laser) can be mounted, and on which a large number of optical transmission channels (such as optical fibers) can be mounted efficiently. At the same time, a purpose of the present invention is to provide a data processing apparatus employ-

ing such a board with built-in optical transmission channel and a fabrication method for such a board with built-in optical transmission channel.

SUMMARY OF THE INVENTION

The 1st aspect of the present invention is a fabrication method for an optical transmission channel board comprising:

a first step of forming on a substrate a layer containing an electrically conductive material; and

a second step of patterning said layer containing an electrically conductive material formed on said substrate, and thereby forming circuit patterns at least a part of which is used as an electric circuit and at least a part of which positionally regulates an optical transmission channel.

The 2nd aspect of the present invention is the fabrication method for an optical transmission channel board according to the 1st aspect of the present invention, wherein said circuit pattern which positionally regulates said optical transmission channel forms guide walls for performing the regulation.

The 3rd aspect of the present invention is the fabrication method for an optical transmission channel board according to the 1st aspect of the present invention, wherein said second step of forming said circuit patterns is a step of forming circuit patterns a part of which is used as an optical element marker for positioning an optical element mounted on said optical transmission channel board.

The 4th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 3rd aspect of the present invention, wherein said second step of forming said circuit patterns is a step of forming circuit patterns used as two or all selected from said electric circuit, said guide walls, and said optical element marker.

The 5th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 1st aspect of the present invention, further comprising an A step of stacking after said second step a guide layer onto said circuit pattern which positionally regulates said optical transmission channel.

The 6th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 1st aspect of the present invention, further comprising a B step of machining after said second step an upper part of said circuit pattern used as said electric circuit.

The 7th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 6th aspect of the present invention, further comprising a C step of stacking after said first step a layer composed of a material different from that of said layer containing said electrically conductive material, onto said layer containing said electrically conductive material, wherein

said B step is a step of machining said layer composed of the different material.

The 8th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 2nd aspect of the present invention, further comprising:

a third step of arranging an optical transmission channel on the basis of said circuit pattern used as guide walls;

a fourth step of forming a retention board for retaining an optical transmission channel on said substrate, in such a manner that said circuit pattern and said optical transmission channel are covered; and

a fifth step of removing said substrate from said retention board.

The 9th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 1st aspect of the present invention, wherein said second step is a step of etching said layer containing said electrically conductive material by using a mask corresponding to said circuit patterns, and thereby forming said circuit patterns.

The 10th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 2nd aspect of the present invention, wherein said optical transmission channel is an optical fiber, and wherein

a length of said guide walls measured in a perpendicular direction relative to a surface of said retention board is greater than a radius of said optical fiber.

The 11th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 10th aspect of the present invention, wherein said guide walls are formed with predetermined spacing such that said optical transmission channel substantially contacts with said guide walls.

The 12th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 4th aspect of the present invention, further comprising a sixth step of mounting an optical element on said circuit pattern such that said optical element is arranged above said optical transmission channel, wherein

said optical element is a laser element or a photo receiving element.

The 13th aspect of the present invention is an optical transmission channel board comprising:

an optical transmission channel;

a retention board for retaining said optical transmission channel; and

circuit patterns which are formed on said retention board and a part of which is used as an electric circuit; wherein

said optical transmission channel is positionally regulated by said part of circuit patterns.

The 14th aspect of the present invention is the optical transmission channel board according to the 13th aspect of the present invention, wherein said optical transmission channel is arranged between guide walls formed under said circuit pattern.

The 15th aspect of the present invention is the optical transmission channel board according to the 13th aspect of the present invention, wherein said circuit patterns are formed in a predetermined thickness along a thickness direction of said retention board, and wherein

said optical transmission channel is arranged in middle of said circuit pattern serving as guide walls.

The 16th aspect of the present invention is the optical transmission channel board according to the 14th or the 15th aspect of the present invention, wherein said optical transmission channel is arranged such as to contact substantially with said guide walls.

The 17th aspect of the present invention is the optical transmission channel board according to the 13th aspect of the present invention, wherein said optical transmission channel is embedded in said retention board, while an uppermost part of said optical transmission channel is substantially arranged in plane with an upper surface of said retention board.

The 18th aspect of the present invention is the optical transmission channel board according to the 13th aspect of the present invention, wherein said circuit pattern has a portion lower than an upper surface of said retention board.

The 19th aspect of the present invention is the optical transmission channel board according to the 18th aspect of

the present invention, wherein said portion lower than an upper surface of said retention board is a land part.

The 20th aspect of the present invention is the optical transmission channel board according to the 13th aspect of the present invention, wherein said optical transmission channel is an optical fiber.

The 21st aspect of the present invention is a data processing apparatus comprising:

an optical transmission channel board according to the 13th aspect of the present invention;

at least one semiconductor element selected from a memory LSI and a logic LSI mounted on said optical transmission channel board; and

a laser element and/or a photo receiving element mounted on said part of circuit patterns; wherein

said optical transmission channel board has a plurality of said optical transmission channels.

The 22nd aspect of the present invention is a fabrication method for an optical transmission channel board comprising:

a first step of embedding, on a retention board, circuit patterns formed by patterning a layer containing an electrically conductive material, wherein at least a part of said circuit patterns is used as an electric circuit, while at least a part of said circuit patterns is used as an optical transmission channel marker; and

a second step of removing said circuit pattern for an optical transmission channel marker from said retention board, and thereby fabricating a groove for said optical transmission channels on said retention board.

The 23rd aspect of the present invention is a fabrication method for an optical transmission channel board comprising:

a first step of embedding, on a retention board, circuit patterns formed by patterning a layer containing an electrically conductive material, wherein at least a part of said circuit patterns is used as an electric circuit, while at least a part of said circuit patterns is used as an optical transmission channel marker; and

a second step of removing a part of board portion located between adjustment portions of said circuit pattern, and thereby fabricating a groove for said optical transmission channel on said retention board.

The 24th aspect of the present invention is a fabrication method for an optical transmission channel board according to the 22nd or the 23rd aspect of the present invention, wherein said first step of embedding said circuit patterns is a step of forming a circuit pattern used as an optical element marker for positioning an optical element.

The 25th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 24th aspect of the present invention, wherein said first step of embedding said circuit patterns is a step of forming circuit patterns a part of which is used as said electric circuit and said optical element marker, or alternatively apart of which is used as said optical element marker and said optical transmission channel marker.

The 26th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 24th aspect of the present invention, wherein said first step of embedding said circuit patterns is a step of forming circuit patterns a part of which is used as two or all selected from said electric circuit, said optical element marker, and said optical transmission channel marker.

The 27th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 24th aspect of the present invention, wherein said second step is a step of fabricating said groove by etching using a mask corresponding to said part of board portion.

The 28th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 22nd or the 23rd aspect of the present invention, wherein said layer containing an electrically conductive material is composed of a composite material containing resin and inorganic filler.

The 29th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 22nd or the 23rd aspect of the present invention, wherein said first step is a step of forming said circuit patterns by etching said layer containing an electrically conductive material by using a mask corresponding to said circuit patterns.

The 30th aspect of the present invention is the fabrication method for an optical transmission channel board according to the 22nd or the 23rd aspect of the present invention, further comprising a third step of arranging an optical transmission channel in said groove.

The 31st aspect of the present invention is the fabrication method for an optical transmission channel board according to the 30th aspect of the present invention, further comprising a fourth step of mounting an optical element in said circuit pattern such that said optical element is arranged above said optical transmission channel, wherein

said optical element is at least any one of a laser element and a photo receiving element.

The 32nd aspect of the present invention is the fabrication method for an optical transmission channel board according to any one of the 1st, 22nd, and the 23rd aspects of the present invention, wherein said optical transmission channel is an optical fiber.

The 33rd aspect of the present invention is a board with built-in optical transmission channel comprising:

a board;

circuit patterns formed on said board and including a plurality of wirings; and

a plurality of optical transmission channels embedded in said board; wherein

at least a certain plurality of said optical transmission channels are arranged in a thickness direction of said board, and wherein

in a vicinity of an end portion of each of said optical transmission channels, an optical element electrically connected to said circuit pattern can be optically connected to said optical transmission channel.

The 34th aspect of the present invention is the board with built-in optical transmission channel according to the 33rd aspect of the present invention, wherein said board is a multilayered board containing a plurality of sub-boards, and wherein

in each of said sub-boards, a single optical transmission channel or a plurality of said optical transmission channels are arranged in said thickness direction.

The 35th aspect of the present invention is the board with built-in optical transmission channel according to the 34th aspect of the present invention, wherein a certain plurality of said optical transmission channels are arranged also in a direction substantially perpendicular to said thickness direction.

The 36th aspect of the present invention is the board with built-in optical transmission channel according to the 33rd aspect of the present invention, wherein a plurality of said optical transmission channels are arranged in said thickness direction within a layer of said board.

The 37th aspect of the present invention is the board with built-in optical transmission channel according to the 36th aspect of the present invention, wherein a certain plurality of said optical transmission channels are arranged also in a direction substantially perpendicular to said thickness direction.

The 38th aspect of the present invention is the board with built-in optical transmission channel according to the 33rd aspect of the present invention, wherein said optical transmission channels are embedded between a plurality of said wirings.

The 39th aspect of the present invention is the board with built-in optical transmission channel according to the 33rd aspect of the present invention, wherein each of said optical transmission channels is an optical fiber.

The 40th aspect of the present invention is the board with built-in optical transmission channel according to the 34th aspect of the present invention, wherein said board is composed of a composite material containing resin and inorganic filler.

The 41st aspect of the present invention is the board with built-in optical transmission channel according to the 33rd aspect of the present invention, wherein said optical element is a vertical-cavity surface-emitting laser.

The 42nd aspect of the present invention is the board with built-in optical transmission channel according to the 41st aspect of the present invention, where in a light-emitting surface of said vertical-cavity surface-emitting laser and a surface of said board are mutually opposing, and wherein

a plurality of light emission points are arranged in said light-emitting surface.

The 43rd aspect of the present invention is the board with built-in optical transmission channel according to the 33rd aspect of the present invention, wherein said end portion of each of said optical transmission channels is cut substantially into an angle of 45°.

The 44th aspect of the present invention is the board with built-in optical transmission channel according to the 34th aspect of the present invention, wherein said vicinity of said end portion of each of said optical transmission channels is provided with an inclined surface for optically connecting said end portion of said optical transmission channel with said optical element.

The 45th aspect of the present invention is the data processing apparatus comprising:

a board with built-in optical transmission channel according to the 33rd aspect of the present invention;

said optical element arranged on said board with built-in optical transmission channel; and

a semiconductor element mounted on said board with built-in optical transmission channel.

The 46th aspect of the present invention is a fabrication method for a board with built-in optical transmission channel comprising:

a first step of forming all or a part of circuit patterns;

a second step of forming guiding means for positioning an optical transmission channel, wherein said forming in said second step is carried out using said circuit patterns or alternatively at the same time as the formation of at least a part of said circuit patterns;

a third step of embedding said optical transmission channel using said guiding means, and thereby forming a sub-board; and

a fourth step of preparing a plurality of sub-boards mentioned above, and then stacking a plurality of said sub-boards.

The 47th aspect of the present invention is a fabrication method for a board with built-in optical transmission channel comprising:

a first step of forming all or a part of circuit patterns;

a second step of forming guiding means for positioning an optical transmission channel, wherein said forming in said second step is carried out using said circuit patterns or alternatively at the same time as the formation of at least a part of said circuit patterns; and

a third step of embedding a plurality of above-mentioned optical transmission channels using said guiding means, and thereby forming a board; wherein

in said third step, a certain plurality of said optical transmission channels are arranged in a thickness direction of said board.

The 48th aspect of the present invention is the fabrication method for a board with built-in optical transmission channel according to the 46th or the 47th aspect of the present invention, wherein said first step and said second step are substantially simultaneously carried out, and wherein said guiding means is formed at the same time as the formation of a predetermined wiring included in said circuit patterns.

The 49th aspect of the present invention is the fabrication method for a board with built-in optical transmission channel according to the 46th or the 47th aspect of the present invention, wherein said optical transmission channel is an optical fiber one end face of which is an inclined surface, and wherein said optical fiber is embedded such that said inclined surface is arranged in a direction opposite to a surface of said board where an optical element electrically connected to said circuit pattern is mounted.

An example of a board with built-in optical transmission channel according to the present invention described above comprises: circuit patterns formed on a board; and a plurality of optical transmission channels embedded in the board, wherein a plurality of the optical transmission channels are arranged in the thickness direction of the board. Thus, an optical element can be mounted above the vicinity of the end portion of each optical transmission channel, so that a large number of optical transmission channels can be arranged efficiently. This arrangement realizes a fabrication method for a board with built-in optical transmission channel permitting optical connection with an optical element and realizing efficient arrangement of a large number of optical transmission channels.

An aspect of the present invention provides: an optical transmission channel board which can be fabricated in a simpler fabrication process; its fabrication method; and a data processing apparatus employing this optical transmission channel board.

Another aspect of the present invention provides: an optical transmission channel board which simplifies a centering process between an optical element and an optical transmission channel end fewer, or does not need a centering process; its fabrication method; and a data processing apparatus employing an optical transmission channel board. Yet another aspect of the present invention provides the advantage of permitting optical connection with an optical element and realizing efficient arrangement of a large number of optical transmission channels.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view schematically showing a configuration of an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **2**(*a*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **2**(*b*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **2**(*c*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **2**(*d*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **3**(*a*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **3**(*b*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **3**(*c*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **3**(*d*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **4**(*a*) is a process sectional view illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **4**(*b*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **5** is a sectional view illustrating optical connection between an optical element **30** and an optical fiber **20** according to Embodiment 1 of the present invention.

FIG. **6** is a sectional view illustrating optical connection between an optical element **30** and an optical fiber **20** according to Embodiment 1 of the present invention.

FIG. **7** is a sectional view schematically showing a configuration in which an optical element **30** is mounted on an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **8**(*a*) is a sectional view showing a modification of an optical transmission channel board **100** according to the present invention.

FIG. **8**(*b*) is a sectional view showing a modification of an optical transmission channel board **100** according to the present invention.

FIG. **9**(*a*) is a sectional view showing a modification of an optical transmission channel board **100** according to the present invention.

FIG. **9**(*b*) is a sectional view showing a modification of an optical transmission channel board **100** according to the present invention.

FIG. **10**(*a*) is a sectional view showing a modification of an optical transmission channel board **100** according to the present invention.

FIG. **10**(*b*) is a sectional view showing a modification of an optical transmission channel board **100** according to the present invention.

FIG. **11** is a sectional view schematically showing a configuration in which an MCM **35** is mounted on an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **12** is a perspective view schematically showing a configuration of an optical module (data processing apparatus) employing an optical transmission channel board **100** according to Embodiment 1 of the present invention.

FIG. **13**(*a*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 2 of the present invention.

FIG. **13**(*b*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 2 of the present invention.

FIG. **13**(*c*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 2 of the present invention.

FIG. **13**(*d*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 2 of the present invention.

FIG. **13**(*e*) is a diagram illustrating a fabrication method for an optical transmission channel board **100** according to Embodiment 2 of the present invention.

FIG. **14**(*a*) is a diagram illustrating a modification of a fabrication method for an optical transmission channel board **100** according to Embodiment 2 of the present invention.

FIG. **14**(*b*) is a diagram illustrating a modification of a fabrication method for an optical transmission channel board **100** according to Embodiment 2 of the present invention.

FIG. **14**(*c*) is a diagram illustrating a modification of a fabrication method for an optical transmission channel board **100** according to Embodiment 2 of the present invention.

FIG. **14**(*d*) is a diagram illustrating a modification of a fabrication method for an optical transmission channel board **100** according to Embodiment 2 of the present invention.

FIG. **15** is a main part enlarged perspective view which shows wirings **12** of an optical transmission channel board **100** according to Embodiments 1 and 2 of the present invention.

FIG. **16** is a main part enlarged perspective view which shows wirings **12** of an optical transmission channel board **100** according to Embodiments 1 and 2 of the present invention.

FIG. **17** is a plan view schematically showing a configuration of an optical fiber **20** which has a Y branching section **23** on an optical transmission channel board **100** according to Embodiments 1 and 2 of the present invention.

FIG. **18** is a partial enlarged perspective view showing an optical element **30** and a portion around optical fibers **20** of an optical transmission channel board **100** according to Embodiments 1 and 2 of the present invention.

FIG. **19** is a partial enlarged perspective view showing an optical element **30** and a portion around optical fibers **20** of an optical transmission channel board **100** according to Embodiments 1 and 2 of the present invention.

FIG. **20** is a partial enlarged perspective view showing an optical element **30** and a portion around optical fibers **20** of an optical transmission channel board **100** according to Embodiments 1 and 2 of the present invention.

FIG. **21** is a perspective view schematically showing a configuration of an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **22**(*a*) is a process sectional view illustrating a fabrication method for an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **22**(*b*) is a process sectional view illustrating a fabrication method for an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **22**(*c*) is a process sectional view illustrating a fabrication method for an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **22**(*d*) is a process sectional view illustrating a fabrication method for an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **23**(*a*) is a process sectional view illustrating a fabrication method for an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **23**(*b*) is a process sectional view illustrating a fabrication method for an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **23**(*c*) is a process sectional view illustrating a fabrication method for an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **23**(*d*) is a process sectional view illustrating a fabrication method for an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **24** is a process sectional view illustrating a fabrication method for an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **25** is a main part enlarged sectional view showing a groove **122** and an optical fiber **120** of an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **26** is a sectional view illustrating optical connection between an optical element **130** and an optical fiber **120** of an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **27** is a sectional view illustrating optical connection between an optical element **130** and an optical fiber **120** of an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **28** is a sectional view schematically showing a configuration in which an MCM **135** is mounted on an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **29** is a perspective view schematically showing a configuration of an optical module (data processing apparatus) employing an optical transmission channel board **200** according to Embodiment 3 of the present invention.

FIG. **30**(*a*) is a main part enlarged view showing a groove **122** of an optical transmission channel board **200** according to Embodiment 4 of the present invention.

FIG. **30**(*b*) is a main part enlarged view showing a state in which an optical fiber **120** is placed in a groove **122** of an optical transmission channel board **200** according to Embodiment 4 of the present invention.

FIG. **30**(*c*) is a main part enlarged view showing a state in which an optical fiber **120** is placed in a groove **122** of an optical transmission channel board **200** according to Embodiment 4 of the present invention.

FIG. **30**(*d*) is a main part enlarged view showing a state in which an optical fiber **120** is placed in a groove **122** of an optical transmission channel board **200** according to Embodiment 4 of the present invention.

FIG. **31**(*a*) is a main part enlarged view showing a groove **122** of an optical transmission channel board **200** according to a modification of the present invention.

FIG. **31**(*b*) is a main part enlarged view showing a state in which an optical fiber **120** is placed in a groove **122** of an optical transmission channel board **200** according to a modification of the present invention.

FIG. **32** is a plan view schematically showing a state in which an optical fiber **120** having a Y branching section **123** is placed on an optical transmission channel board **200** according to the present invention.

FIG. **33** is a sectional view showing relation between an optical fiber **120** and an edge emitting type element **160** which are placed and mounted on an optical transmission channel board **200** according to the present invention.

FIG. **34** is a perspective view schematically showing a configuration of a board with built-in optical transmission channel **300** according to Embodiment 5 of the present invention.

FIG. **35** is a sectional view schematically showing a configuration of a board with built-in optical transmission channel **300** according to Embodiment 5 of the present invention.

FIG. **36** is a sectional view illustrating optical connection between an optical element **230** and an optical transmission channel **220**.

FIG. **37** is a sectional view illustrating optical connection between an optical element **230** and an optical transmission channel **220**.

FIG. **38** is a sectional view illustrating optical connection between an optical element **230** and a plurality of optical transmission channels **220***a* and **220***b*.

FIG. **39** is a sectional view illustrating optical connection between an optical transmission channel **220***a* and an optical transmission channel **220***b*.

FIG. **40**(*a*) is a process sectional view illustrating a fabrication method for a board with built-in optical transmission channel **300**.

FIG. **40**(*b*) is a process sectional view illustrating a fabrication method for a board with built-in optical transmission channel **300**.

FIG. **40**(*c*) is a process sectional view illustrating a fabrication method for a board with built-in optical transmission channel **300**.

FIG. **40**(*d*) is a process sectional view illustrating a fabrication method for a board with built-in optical transmission channel **300**.

FIG. **41**(*a*) is a process sectional view illustrating a fabrication method for a board with built-in optical transmission channel **300**.

FIG. **41**(*b*) is a process sectional view illustrating a fabrication method for a board with built-in optical transmission channel **300**.

FIG. **41**(*c*) is a process sectional view illustrating a fabrication method for a board with built-in optical transmission channel **300**.

FIG. **41**(*d*) is a process sectional view illustrating a fabrication method for a board with built-in optical transmission channel **300**.

FIG. **42**(*a*) is a process sectional view illustrating a fabrication method for a board with built-in optical transmission channel **300**.

FIG. **42**(*b*) is a process sectional view illustrating a fabrication method for a board with built-in optical transmission channel **300**.

FIG. **43** is a sectional view schematically showing a configuration of a board with built-in optical transmission channel **300** on which an optical element **230** is mounted.

FIG. **44** is a sectional view schematically showing a configuration of a board with built-in optical transmission channel **300** on which an MCM **235** is mounted.

FIG. **45**(*a*) is a process sectional view illustrating another fabrication method for a board with built-in optical transmission channel **300**.

FIG. **45**(*b*) is a process sectional view illustrating another fabrication method for a board with built-in optical transmission channel **300**.

FIG. **45**(*c*) is a process sectional view illustrating another fabrication method for a board with built-in optical transmission channel **300**.

FIG. **46** is a sectional view schematically showing another configuration of a board with built-in optical transmission channel **300**.

FIG. **47** is a sectional view schematically showing a configuration of a board with built-in optical transmission channel **300**.

FIG. **48** is a perspective view schematically showing a configuration of an optical module (data processing apparatus) employing a board with built-in optical transmission channel **300**.

FIG. **49** is a plan view schematically showing a configuration of an optical fiber **220** having a Y branching section **223**.

FIG. **50** is a perspective view showing a prior art optical module **1000**.

FIG. **51** is a sectional view showing a prior art optical module **2000**.

FIG. **52** is a perspective view illustrating the mounting hierarchy of a prior art communication system apparatus **3000** for performing optical communications.

FIG. **53** is a sectional view showing a prior art wiring board **4000**.

FIG. **54**(*a*) is a plan view showing a prior art wiring board **4000**.

FIG. **54**(*b*) is a sectional view taken along line X-X' in FIG. **54**(*a*).

FIG. **55** is a perspective view showing a prior art light wiring board **5000**.

DESCRIPTION OF REFERENCE NUMERALS

10 Board
11 Reflection surface
12 Wiring
13 Wiring
15 Circuit pattern
16, **17** Guide layer
18 Guide wall
20 Optical fiber
21 End face
22 Groove
23 Branching section
25 Light (optical signal)
26 Level difference
28 Land
30 Optical element
32 Connection member
34 Interposer
36 Mirror
37 Stopper
40 Carrier sheet
42 Metal layer
50, **51**, **52**, **53** Mask
60 Edge emitting type element
100 Optical transmission channel board
110 Board
111 Reflection surface
112 Wiring (groove-use wiring)
113 Wiring
120 Optical fiber
121 End face
122 Groove
123 Branching section
125 Light (optical signal)
130 Optical element
131 Electronic components
132 Connection member
134 Interposer
140 Carrier sheet
142 Metal layer
150, **51** Mask
200 Optical transmission channel board
210 Board
210*a*, **210***b* Sub-board
211 Reflection surface
212 Wiring
213 Wiring
215 Circuit pattern
216, **217** Guide layers
218 Guide wall
220 Optical transmission channel (optical fiber)
221 End face
222 Groove
223 Branching section
225 Light (optical signal)
227 Optical connector
230 Optical element
232 Connection member
234 Interposer
235 MCM
236 Via hole (interlayer connection member)
237 Electric input and output section
240 Carrier sheet
242 Metal layer
250, **251**, **252**, **253** Mask
300 Board with built-in optical fiber
1000 Optical module
2000 Optical module
3000 Communication system apparatus
4000 Wiring board
5000 Optical wiring board

PREFERRED EMBODIMENTS OF THE INVENTION

Embodiments of the present invention are described below with reference to the drawings. For the simplicity of description of the drawings, components having substantially the same function are designated by like reference numerals. It should be noted that the present invention is not limited to the embodiments described below.

Embodiment 1

An optical transmission channel board according to Embodiment 1 and its fabrication method are described below with reference to FIGS. **1-4**.

FIG. **1** is a perspective view schematically showing the configuration of an optical transmission channel board **100** of Embodiment 1.

As shown in FIG. **1**, the optical transmission channel board **100** of Embodiment 1 comprises: a board **10**; and circuit patterns **15** including a plurality of wirings **12** formed on the board **10**. A plurality of optical fibers **20** are arranged between each the wiring **12** of the circuit patterns **15**, respectively. An optical transmission channel of the present invention indicates an optical fiber **20** of Embodiment 1. Thus, Embodiment 1 is described for the case of optical fibers. However, an "optical transmission channel" in the present specification indicates a line-shaped member capable of transmitting light. This holds also in the other embodiments described below.

When viewed from the above of the board **10** (viewed from the normal direction of the board **10**), the optical fibers

20 are arranged between the wirings 12 such as to contact substantially with the wirings 12. More specifically, the optical fibers 20 are arranged in grooves 22 formed between the wirings 12, and hence are built in the board 10. In other words, the grooves 22 formed between the wirings 12 serve as mounting sections for the optical fibers 20. Further, in Embodiment 1, the upper most portions of the optical fibers 20 are substantially in plane with the upper surfaces of the circuit patterns 15 and the wirings 12. A method for aligning them in plane is described later in a fabrication method for the optical transmission channel board 100.

In the optical transmission channel board (board with built-in optical fiber) 100 shown in FIG. 1, an optical element 30 is mounted with reference to a marker (an optical element marker, hereafter) for positioning the optical element. The optical element is electrically connected to the wirings 12, and optically connected to the optical fibers 20. Although the optical element marker is not shown in the figure, a typical marker is composed of positioning reference planes 1103*a*, 1103*b*, and 1103*c* used in the prior art of FIG. 50. The optical element 30 is a laser element such as a semiconductor laser, or alternatively a photo receiving element such as a photo-diode. In Embodiment 1, the optical element 30 is arranged such as to substantially contact with the upper portions of the optical fibers 20.

In Embodiment 1, the board 10 serving as an example of a retention board of the present invention is composed of a composite material containing resin (such as a thermosetting resin and a thermoplastic resin) and inorganic filler. In this example, a thermosetting resin is used as the resin of the composite material. The board 10 may be composed only of thermosetting resin without inorganic filler. The thermosetting resin is an epoxy resin or the like. When added, the inorganic filler is Al_2O_3, SiO_2, MgO, BN, AlN, or the like. Various physical properties (such as the thermal expansion coefficient) can be controlled when the inorganic filler is added. Thus, the board 10 is preferably formed of a composite material containing inorganic filler. In Embodiment 1, inorganic filler of 100 weight units or more (preferably 140-180 weight units) is contained relative to the thermosetting resin of 100 weight units.

The role of inorganic filler is as follows. When Al_2O_3, BN, or AlN is added as inorganic filler, the thermal conductivity of the board 10 is improved. Further, when an appropriate inorganic filler is selected, the thermal expansion coefficient can be adjusted. In case that the thermal expansion coefficient is rather increased by the resin component, the addition of SiO_2, AlN, or the like can decrease the thermal expansion coefficient. In an appropriate case, when MgO is added, the thermal conductivity is improved while the thermal expansion coefficient is increased. Further, when Si_2O (especially, amorphous SiO_2) is added, the thermal expansion coefficient is decreased while the dielectric constant is reduced.

A fabrication method for an optical transmission channel board according to Embodiment 1 is described below.

An optical transmission channel board 100 of Embodiment 1 is fabricated using a transfer method. More specifically, a metal layer formed on a supporting board is patterned so that circuit patterns 15 are formed that include: a plurality of wirings 12, other wirings 13, and wirings used as an optical element marker. Then, optical fibers 20 are arranged between the wirings 12 of the circuit patterns 15. After that, a material containing resin is deposited on the supporting board so as to cover the circuit patterns 15 and the optical fibers 20. Then, when the supporting board is removed, the circuit patterns 15 are exposed on the surface so that the optical transmission channel board 100 of Embodiment 1 is obtained.

The above-mentioned fabrication method for an optical transmission channel board is described below in further detail with reference to FIGS. 2-4.

As shown in FIG. 2(*a*), prepared first is a carrier sheet (transfer formation material) 40 on which a metal layer 42 serving as an example of a layer containing an electrically conductive material of the present invention is formed. The metal layer 42 is composed of copper or the like. The carrier sheet 40 serving as an example of a substrate of the present invention is composed of a metallic foil (a copper or aluminum foil), a resin sheet, or the like. The thickness values of the metal layer 42 and the carrier sheet 40 are approximately 3-50 μm and approximately 25-200 μm, respectively.

Then, as shown in FIG. 2(*b*), a mask 50 corresponding to the circuit patterns 15 is placed above the metal layer 42. The metal layer 42 is then etched. As a result, as shown in FIG. 2(*c*), circuit patterns 15 are formed that include: the wirings 12 located in the surrounding portion of the optical fibers 20; other wirings 13; and the wiring used as an optical element marker.

After the patterning by the above-mentioned etching, walls for guiding the optical fibers 20 to be arranged are formed in at least a part of the circuit patterns 15. In Embodiment 1, the guide walls are formed on top of the wirings 12.

More specifically, as shown in FIG. 2(*c*), a mask 51 having an opening in the portions corresponding to the wirings 12 is arranged above the carrier sheet 40. Then, as shown in FIG. 2(*d*), a guide layer 16 serving as a layer constituting the guide walls is deposited on the wirings 12. In an example, the guide layer 16 is composed of metal, and formed by sputtering. Vapor deposition, plating, a deposition method, or the like may be used in place of sputtering. The reason why the sputtering is used in the formation of the guide layer 16 in Embodiment 1 is that this method provides a preferable fabrication accuracy.

In case that the height of the guide walls for supporting the optical fibers 20 is insufficient even after the guide layer 16 is formed, a mask 52 is arranged above the guide layer 16 as shown in FIG. 3(*a*), and then another guide layer 17 is deposited on the guide layer 16 serving as a base. The mask 52 may be the same as the previous mask 51. The material constituting the guide layer 17 may be the same as, or different from, the material constituting the guide layer 16. The material constituting the guide layers 16 and 17 is not limited to a metal, and may be another material (such as ceramics). The method of deposition to be used is not limited to sputtering, and may be another technique such as a flame deposition method.

As such, as shown in FIG. 3(*b*), guide walls 18 constructed from the guide layer 16 and the guide layer 17 is formed on the wirings 12. The guide walls 18 constitute grooves 22 (optical fiber mounting sections) in which the optical fibers 20 are to be mounted. In Embodiment 1, the total thickness of the wiring 12 and the guide wall 18 (guide layers 16 and 17) is greater than the radius of the optical fiber 20 arranged between the guide walls 18. This configuration ensures the optical fibers 20 to contact substantially with the guide walls 18, and hence reduces mounting discrepancy.

Then, as shown in FIG. 3(*c*), the optical fibers 20 are arranged between the guide walls 18 (between the wirings 12) That is, the optical fibers 20 are inserted into the grooves 22 formed between the guide walls 18 (or the wirings 12).

The guide walls **18** have such spacing that the optical fibers **20** substantially contact with the guide walls **18** when arranged therebetween. A slight excess in the spacing is allowable. More specifically, this excess is preferably 0.1 μm or less between each optical fiber **20** and each of the right and left guide walls **18**. The optical fibers **20** are arranged such as to contact with the carrier sheet **40**.

Then, as shown in FIG. **3**(*d*), a material containing resin is deposited on the carrier sheet **40** so that a board (insulating board) **10** is formed. This deposition is performed such that the circuit patterns **15** and the optical fibers **20** are covered. That is, the material constituting the board **10** covers: the circuit patterns **15** including the wirings **12** and **13**; the guide walls **18**; and the optical fibers **20**. In Embodiment 1, the material constituting the board **10** is deposited in a thickness of three times or more of the radius of the optical fiber **20**. The thickness of the board **10** can be 0.18-0.4 mm or the like.

Then, as shown in FIG. **4**(*a*), the board **10** is reversed and the carrier sheet **40** is removed. As a result, an optical transmission channel board **100** of Embodiment 1 is obtained. That is, the circuit patterns **15** on the carrier sheet **40** are separated so that the transfer is completed. The board **10** may be reversed after the removal of the carrier sheet **40**.

In the fabrication method of Embodiment 1, the circuit patterns **15** and the optical fibers **20** simultaneously contact with the carrier sheet **40** in the state of FIG. **3**(*d*). Thus, in the state of FIG. **4**(*a*), the upper surface of the circuit patterns **15** and the uppermost parts of the optical fibers **20** are substantially in plane. Further, the resin surface (more specifically, the surface of the composite material) of the board **10** is substantially in plane with the upper surface of the circuit patterns **15** and the uppermost parts of the optical fibers **20**.

Further, according to the fabrication method of Embodiment 1, the optical fibers **20** can be simply embedded (built) in the board **10**. Further, in comparison with the case that the optical fibers **20** are provided on the surface of the board **10**, the optical fibers **20** are protected more appropriately.

After that, as shown in FIG. **4**(*b*), when an optical element **30** and an electronic component **31** are mounted on the circuit patterns **15** exposed in the surface of the board **10**, an optical module is obtained.

The optical element **30** is a semiconductor laser or the like, and is arranged such as to substantially contact with the top of the optical fibers **20** in Embodiment 1. The phrase "arranged above an optical transmission channel" according to the present invention includes the state "arranged such as to substantially contact with the top of an optical transmission channel (optical fiber **20**)". The optical element **30** may be a photo receiving element (such as a photo-diode). The electronic component **31** mounted on the portion of the wirings **13** among circuit patterns **15** is a semiconductor element (such as a logic LSI) In the example shown in FIG. **4**(*b*), the electronic component (semiconductor element) **31** is electrically connected to the wirings **13** through solder balls **32**.

The optical element **30** and the optical fibers **20** can be optically connected, for example, as shown in the schematic sectional view of FIG. **5**. That is, as shown in FIG. **5**, a reflection surface (inclined surface) **11** is formed in a part of board **10**, so that optical connection by light (an optical signal) **25** is established between the optical element **30** and the optical fibers **20** via the reflection surface **11**. In an example, the reflection surface **11** is obtained by fabricating an inclined surface in the board **10**, and then forming a metal layer (such as an Au layer) on the surface of the inclined surface. Alternatively, an optical component (mirror) having a reflection surface **11** may be placed on the board **10**.

Further alternatively, as shown in the schematic sectional view of FIG. **6**, an end face **21** of the optical fiber **20** may be cut aslant (such as a 45° cut) so that the light **25** should be reflected in the end face **21**. This permits optical connection between the optical element **30** and the optical fiber **20**. In the configuration shown in FIGS. **5** and **6**, a transparent medium may be present in the path of the light **25** between the optical element **30** and the optical fiber **20**. The transparent medium is air, glass, transparent resin, or the like. The transparent resin is a material which permits optical connection between the optical element **30** and the optical fiber **20** and which transmits light of a wavelength of 850 nm, 1330 nm, and 1550 nm or the like. More specifically, the transparent resin is composed of polyimide, epoxy aramid, or the like. Alternatively, an optical component (such as a lens) may be arranged between the optical element **30** and the optical fiber **20**. The configurations of FIGS. **5** and **6** where the optical element **30** and the optical fiber **20** are not in close contact with each other are different from those of FIGS. **1** and **4**(*b*), and corresponds to the configuration of FIG. **7** described later.

When the optical element **30** is mounted on the portion of the wirings **12** in the circuit patterns **15**, pad sections may be formed on the wirings **12** so that element terminals of the optical element **30** may be connected to the pad sections by wire bonding. Nevertheless, such wire bonding connection is disadvantageous in high speed characteristics. Thus, as an example shown in FIG. **7**, the connection between the optical element **30** and the wirings **12** is preferably realized by flip chip mounting or the like using connection members (such as bumps and solder balls) **32**. In this case, lands are formed in the portions of the wirings **12** with which the connection members **32** contact.

As described above, in Embodiment 1, the wirings **13** and the wirings **12** are simultaneously fabricated as the circuit patterns **15** by using a single mask. The guide walls **18** for positioning the optical fibers **20** are formed with reference to the wirings **12**. That is, in Embodiment 1, the wirings **12** and the portions between the guide walls **18** used for positioning the optical fibers (correspond to the previous guide grooves **104**) are fabricated as the circuit patterns **15** in the same process. This simplifies the fabrication process in comparison with the prior art.

In Embodiment 1, the optical element marker (not shown) included in the circuit patterns **15** corresponds to the positioning reference planes **103***a*, **103***b*, and **103***c* for positioning the previous optical element. The portions between the guide walls **18** for positioning the optical fibers **20** correspond to the previous guide grooves **104**. The wirings **12** included in the circuit patterns **15** serve as a reference in the forming of the guide walls **18**. That is, the optical element marker for positioning the optical element **30** and the guide walls **18** for positionally regulating the optical fibers **20** are formed using the same mask **50**. Thus, the optical element marker and the guide walls are aligned automatically. This resolves the problem of centering, and permits optical connection between the optical element **30** and the optical fibers **20**.

In a possible case that a centering process is to be performed in the optical transmission channel board **100** of Embodiment 1 in order to further improve the optical connection, rough centering has already been achieved with a precision better than that of the prior art configuration. Thus, fine centering solely is sufficient.

A first step of the present invention corresponds to the step shown in FIG. **2**(*a*), for example. A second step of the present invention corresponds to the step shown in FIGS. **2**(*b*)-**2**(*c*), for example. An A step of the present invention corresponds to the step shown in FIGS. **2**(*d*)-**3**(*b*) **2**, for example. A third step of the present invention corresponds to the step shown in FIG. **3**(*c*), for example. A fourth step of the present invention corresponds to the step shown in FIG. **3**(*d*), for example. A fifth step of the present invention corresponds to the step shown in FIG. **4**(*a*) for example. A sixth step of the present invention corresponds to the step shown in FIG. **4**(*b*), for example.

A part of circuit patterns used as an electric circuit of the present invention corresponds to the wirings **13** of Embodiment 1. A part of circuit patterns for positionally regulating an optical transmission channel of the present invention corresponds to the wirings **12** of Embodiment 1.

The function of the optical element marker may be performed by a part of circuit patterns for positioning an optical transmission channel. The function may be performed by a circuit pattern for an electric circuit. The wirings **12** for positioning an optical transmission channel may be used as an electric circuit.

In Embodiment 1, the upper surface of the board **10** and the uppermost portions of the optical fibers **20** are substantially in plane, and arranged so as to contact with the guide walls **18**. However, as shown in FIG. **8**(*a*), the spacing between the wirings **12** may be smaller than the diameter of the optical fiber **20** so that the upper surface of the board **10** may be out of plane with the uppermost portions of the optical fibers **20**. Further, the guide walls **18** may be formed such as to contact with the optical fibers in a manner shown in FIG. **8**(*b*).

Alternatively, as shown in FIG. **9**(*a*), a carrier sheet **40** may serve as a retention board without the use of a board **10**. In this case, optical fibers **20** are arranged between wirings **12** so that the board is use as an optical transmission channel board. Further, guide walls **18** may be provided as shown in FIG. **9**(*b*) so that optical fibers **20** may be arranged. The optical fibers **20** may be arranged such as to contact or not contact with the retention board (carrier sheet **40**).

In Embodiment 1, the guide layers **16** and **17** are stacked. However, as shown in FIG. **10**(*a*), a layer containing an electrically conductive material may have a thickness permitting the positioning of an optical fiber, so that guide walls **18** may be formed solely by wirings **12**.

As shown in FIG. **11**, the optical fibers **20** may be optically connected to optical elements within an MCM (multi-chip module) **35**, in place of a single discrete optical element **30**. In this example, a plurality of electronic components **33***a* and **33***b* are mounted on an interposer **34** so that an MCM **35** is constructed. At least one of the electronic components **33***a* and **33***b* is an optical element. Both electronic components **33***a* and **33***b* may be laser elements (semiconductor lasers), or may be photo receiving elements (photo-diodes). Alternatively, they may be a combination of a laser element and a photo receiving element. In an example, an opening is formed in a part of the interposer **34** corresponding to the optical path between the optical elements and the optical fibers. An optical component (such as a lens) may be arranged in the position of the opening. The optical elements **33***a* and **33***b* may be mounted on the back side of the interposer **34**.

In the prior art, position adjustment has been necessary between the grooves **22**, the interposer **34**, and the electronic components **33***a* and **33***b* corresponding to the optical fibers **20**. However, according to the fabrication method of Embodiment 1, the optical fibers **20** are positioned on the basis of the positions of the grooves **22** formed by the wirings **12**. Further, the interposer **34** is positioned by the optical element marker formed using the same mask as that used in the formation of the wirings **12**. This simplifies the position adjustment between the optical fibers **20** and the interposer **34**, and hence simplifies the centering process in comparison with the prior art.

In the optical transmission channel board **100** of Embodiment 1, the wirings **12** and the other wirings (such as **13**) are formed simply by a transfer method. Thus, even electronic components other than optical elements (semiconductor elements) can be mounted similarly to the case of a typical printed circuit board. FIG. **12** shows an optical module in which electronic components **31** (**31***a*, **31***b*, **31***c*, **31***d*, **31***e*) in addition to optical elements **30***a* and **30***b* are mounted on an optical transmission channel board **100**. The optical module shown in FIG. **12** can be used as a data processing apparatus. This module is described below in further detail.

The optical element **30***a* is a laser element, and may be a vertical-cavity surface-emitting laser (VCSEL). On the other hand, the optical element **30***b* is a photo receiving element, and may be a photo-diode element having a plurality of photo-receiving sections. For the simplicity of understanding the configuration of Embodiment 1, grooves **22** are shown without optical fibers **20** to be optically connected to the optical element **30***a*.

The laser element **30***a* is connected to a driver IC **31***a*. The driver IC **31***a* is connected to an LSI chip (such as a logic LSI like an image processing LSI) **31***b*. The LSI chip **31***b* is connected to a memory chip **31***c*. The photo receiving element **30***b* is connected to the LSI chip **31***b* via an amplifier (preamplifier) **31***d* and an amplifier **31***e*. The electronic components **31** are mutually connected through the wirings **13** in the circuit patterns **15**.

The problem of centering is resolved by the configuration of optical element markers for positioning the wirings **12** and the optical elements. Thus, the wirings **13** may be formed on the board **10** separately in a step other than a transfer process (for example, in an independent and later step). However, from the perspective of fabrication procedure, cost, and the like, it is efficient to fabricate the wirings **13** in the same step as that of the wirings **12** and the optical element markers similarly to the fabrication method of Embodiment 1.

The optical module (data processing apparatus) shown in FIG. **12** can perform optical transmission through the optical fibers **20**. Thus, mass data can be transmitted at a high speed. Further, this module fabricated by the method of Embodiment 1 has a low fabrication cost.

That is, the circuit patterns **15** (including the wirings **12**) and the grooves **22** are formed integrally. This simplifies the fabrication process, and reduces the fabrication cost which has been increased by a larger tolerance discrepancy in the prior art. Thus, the cost can be reduced in optical modules presently used in optical communications (such as the Internet and telephone). This accelerates the spread of such optical modules.

Further, the cost reduction permits the use of economical optical transmission in within-the-board transmission (level **2**) in the communication system apparatus **3000** shown in FIG. **52**. This improves the speed of within-the-board transmission. As such, the present invention is applicable to the bookshelf type communication system apparatus **3000** shown in FIG. **52**. Similarly, the optical transmission channel board or optical module **100** of the present invention may be used as a main apparatus such as a next-generation high

performance optical I/O module and a data processing apparatus (like an image processing apparatus).

Embodiment 2

A fabrication method for an optical transmission channel board according to Embodiment 2 is described below. FIGS. **13**(*a*)-**13**(*e*) are sectional views of an optical transmission channel board used for describing a fabrication method for an optical transmission channel board according to Embodiment 2.

First, starting from the state shown in FIG. **2**(*a*), guide layers **16** and **17** are stacked on a metal layer **42** so that the state shown in FIG. **13**(*a*) is achieved. Then, as shown in FIG. **13**(*b*), these layers (**17**, **16**, **42**) are etched using a mask **53** for defining the shape of circuit patterns **15**. As a result, circuit patterns **15** are formed that include: wirings **12** for constituting grooves **22**; other wirings **13**; and an optical element marker for positioning an optical element.

Then, as shown in FIG. **13**(*c*), the guide layers **16** and **17** on top of the wirings **13** are etched using a mask **54** for defining the shape of the wiring **13** portion. As a result of this etching, guide walls **18** and wirings **13** are formed as shown in FIG. **13**(*d*) This configuration is similar to that of FIG. **3**(*b*) in Embodiment 1. After that, when processes similar to those of FIG. **3**(*c*) and its subsequent are performed, an optical transmission channel board **100** or optical module shown in FIG. **13**(*e*) is obtained.

That is, in Embodiment 1, the guide layers **16** and **17** have been stacked after the formation of the wirings **12**. In contrast, in Embodiment 2, the wirings **12** are formed after the stacking of the guide layers **16** and **17**.

A layer composed of a material different from a layer containing an electrically conductive material according to the present invention corresponds to each of the guide layers **16** and **17** of Embodiment 2. In place of these two layers which may be composed of mutually different materials, a single layer may be used that has a predetermined thickness. Alternatively, more than two layers may be stacked. That is, it is sufficient that the optical fibers **20** can be positioned.

A "C" step of the present invention corresponds to the step shown in FIG. **13**(*a*), for example. A "B" step of the present invention corresponds to the step shown in FIGS. **13**(*c*)-**13**(*d*) for example.

The mask **54** of Embodiment 2 has a shape corresponding to the wirings **13**. However, it is sufficient that at least the portion constituting the guide walls **18** (corresponding to the wirings **12**) is covered.

In Embodiment 2, the guide layers **16** and **17** on top of the wirings **13** are removed. However, these layers need not be removed, and may be kept embedded in the board **10**.

In Embodiment 2, the guide layers **16** and **17** are stacked. However, as shown in FIG. **10**(*b*), the layer containing an electrically conductive material may have a thickness sufficient for positioning the optical fibers, so that the guide walls **18** may be formed only by the wirings **12**. In this case, an unnecessary portion (indicated by a dotted line in the figure) of the thickness of the wirings **13** serving as a circuit pattern used as an electric circuit of the present invention may be removed. This portion corresponds to the upper portion of the wirings **13**, since the optical transmission channel board **100** is retained upside down during the fabrication.

In Embodiment 2, the grooves **22** and the circuit patterns **15** are fabricated simultaneously using the mask **53** corresponding to the circuit patterns **15**. However, as shown in FIGS. **14**(*a*)-**14**(*d*), the circuit patterns **15** may be formed after the formation of the grooves **22**. That is, as shown in FIG. **14**(*b*), the grooves **22** are first formed using a mask **55** corresponding to the grooves **22**. At the same time, an optical element marker for positioning the optical element is formed, although not illustrated. Then, etching is performed using a predetermined mask, so that the guide walls **18** and the circuit patterns **15** (including the wirings **12** and the wirings **13**) are formed as shown in FIG. **14**(*c*). Since FIG. **14**(*c*) shows a configuration similar to that of FIG. **3**(*b*), when the steps after FIG. **3**(*c*) are performed, an optical transmission channel board **100** or optical module shown in FIG. **14**(*d*) is obtained.

Further features and further modifications of the optical transmission channel board **100** are described below with reference to other drawings.

As described above, the steps shown in FIGS. **2**(*a*)-**4**(*a*) described in Embodiment 1 are performed so that the circuit patterns **15** including the wirings **12** are formed, the uppermost portions of the optical fibers **20** are substantially in plane with the upper surface of the circuit patterns **15**. However, a predetermined portion or the entirety of the circuit patterns **15** can be depressed relative to the resin surface (or composite material surface) of the board **10**.

For example, as shown in FIG. **15**, the upper surface of the wirings **12** can be depressed relative to the surface (resin surface) **10***a* of the board **10** by the following method, so that a level difference **26** can be formed.

That is, in the patterning in FIG. **2**(*b*), in addition to the unnecessary portion of the metal layer **42**, a carrier sheet **40** portion constituting the base for the circuit patterns **15** are also etched. Then, in a resin application step (that is, a step of applying a composite material) shown in FIG. **3**(*d*), the resin goes deeper than the surface of the wirings **12** toward the carrier sheet **40**. As a result, a level difference **26** is formed between the surface **10***a* of the board **10** and the upper surface of the wirings **12**. Similarly in Embodiment 2, when a predetermined portion of the carrier sheet **40** is etched in the patterning in FIG. **13**(*b*), a level difference **26** is formed.

When a land **28** used as a mounting section for an optical element **30** is formed in a part of the wiring **12** (typically, in an end portion), the level difference **26** serves as a dam for retaining the solder. That is, the solder serves as a solder resist, or assists a solder resist. The land **28** portion is usually wider than the wiring section. Thus, the land **28** may be formed as shown in FIG. **16**. In this case, when the guide walls **18** are designed such as not to be formed under the wiring **12** where the land **28** is located, a mounting region (a groove **22**) for the optical fiber **20** is appropriately secured.

The land **28** shown in FIG. **16** is a rectangular land, but may be a circular land. Further, description has been made for the case of the wiring **12**. However, a land having such a configuration may be fabricated in another wiring (such as a wiring **13**) in the circuit patterns **15**.

In the optical transmission channel board **100** of embodiments 1 and 2, the optical fibers **20** are embedded in the board **10**. Thus, even in case that the optical fibers **20** have a Y branching section **23** as shown in FIG. **17** and hence are fragile, the present embedding enforces the optical fibers **20**. More specifically, as shown in FIG. **17**, the optical fiber **20** is embedded into the groove **22** (optical fiber mounting section) formed by the wirings **12** and the guide walls **18** under the wirings. When such optical fibers **20** having a Y branching section **23** are used, an optical module (board with built-in optical fiber) suitable for wavelength multiplexing is provided.

Optical connection between the optical element **30** and the optical fibers **20** can be performed as shown in FIGS. **18**-**20**. FIGS. **18**, **19**, and **20** are partial enlarged perspective views showing the surrounding portion of the optical element **30** and the optical fibers **20**. For simplicity, a yet hidden portion in the optical element **30** is indicated as a shaded region.

In the configuration shown in FIG. **18**, a mirror **36** having a reflection surface **11** is arranged under the optical element **30**. The optical element **30** and the optical fibers **20** are optically connected via the mirror **36**. In this example, the edges of both ends of the mirror **36** are defined by the inside lines of the wirings **12**, so that the mirror **36** is positioned by the wirings **12**.

In the configuration shown in FIG. **19**, stoppers **37** for the optical fibers **20** are formed. In this example, as shown in FIG. **6**, end faces of the optical fibers **20** are cut into 45°, so that optical connection between the optical fibers **20** and the optical element **30** is achieved. The stoppers **37** are formed under the optical element **30**, and arranged in the grooves **22**, for example. The stoppers **37** permit efficient arrangement of the optical fibers **20**.

As shown in FIG. **20**, the wirings to be connected electrically to the optical element **30** need not only be the wirings **12** extended from the optical fiber **20** side, but may also be the wirings **12'** extended from the opposite direction. The wirings **12'** are circuit patterns fabricated with the same positional precision as the wirings **12**. In the example shown in FIG. **20**, lands **28** are formed at the tips of the wirings **12'**, so that the optical element **30** is mounted on the lands **28**.

Embodiments 1 and 2 have been described for the examples of an optical transmission channel board employing optical fibers. However, in place of optical fibers, optical waveguides composed of plane waveguides (PLCs) may be used as optical transmission channels **20**. When optical waveguides composed of plane waveguides (PLCs) are used as optical transmission channels, a plurality of grooves formed on the plane waveguide (PLC) side are engaged with a plurality of the grooves **22**. This improves manufacturability. When wirings **13** are formed on the plane waveguide (PLC) side, or when the optical element **30** is mounted on the plane waveguide (PLC) side, fabrication and the centering problem are further simplified. Nevertheless, from the perspective of cost, the use of optical fibers based on the fabrication method of the present embodiment can be advantageous over the use of the optical waveguides composed of plane waveguides (PLCs).

The present invention has been described above with reference to a preferred embodiment. This description is not a limitation, and hence various modifications can be made.

As described above, the fabrication method for a board with built-in optical transmission channel according to the present invention comprises: a step (a) of patterning a metal layer formed on a supporting board and thereby forming circuit patterns including a plurality of wirings; a step (b) of arranging an optical transmission channel between wirings of said circuit patterns; a step (c) of depositing a material containing resin onto said supporting board in such a manner that said circuit pattern and said optical transmission channel are covered; and a step (d) of removing said supporting board.

In a preferred embodiment, said step (a) includes: a step of preparing a supporting board and a metal layer formed on said supporting board; and a step of etching said metal layer using a mask corresponding to the circuit patterns.

In an example, a step of forming walls used as a guide for arranging an optical transmission channel, in at least a part of said circuit patterns is performed before said step (b).

In a preferred embodiment, at least a part of said walls is composed of metal.

In a preferred embodiment, at least a part of said walls is formed by sputtering.

In a preferred embodiment, said optical transmission channel is an optical fiber. The sum of the thickness values of said wall and said wiring located under the wiring is greater than the radius of said optical fiber.

In a preferred embodiment, in said step (b), said optical transmission channel is arranged such as to contact with said supporting board.

In a preferred embodiment, said optical transmission channel is arranged between said wirings so as to contact with said walls.

In an example, said material containing resin is preferably a composite material containing resin and inorganic filler.

In an embodiment, said optical transmission channel is an optical fiber. In said step (c), said material containing resin is deposited in a thickness of three times or more of the radius of said optical fiber.

In an embodiment, after said step (c) and before or after said step (d), the deposition film composed of said material is reversed in said step (c).

In a preferred embodiment, after said step (d), the uppermost portion of said optical transmission channel is substantially in plane with the upper surface of said circuit patterns.

In a preferred embodiment, a step of mounting electronic components electrically connected to said circuit pattern is further performed after said step (d).

In a preferred embodiment, at least one of said the electronic components is at least one optical element selected from a laser element and a photo receiving element. Said optical element is arranged above said optical transmission channel, or arranged such as to substantially contact with said optical transmission channel.

In an example, a board with built-in optical transmission channel according to the present invention comprises: a board composed of a material containing resin; circuit patterns formed on said board and including a plurality of wirings; and an optical transmission channel arranged between said wirings of said circuit patterns so as to substantially contact with said wirings when viewed from the above of said board.

In a preferred embodiment, the uppermost portion of said optical transmission channel is substantially in plane with the upper surface of said circuit patterns.

In a preferred embodiment, a portion lower than the upper surface of said board is present in at least a part of the upper surface of said circuit patterns.

In a preferred embodiment, the entirety of the upper surface of said circuit patterns is lower than the upper surface of said board.

In a preferred embodiment, said portion lower than the upper surface of said board in said circuit patterns is a land section.

In an example, said optical transmission channel may have a Y branching section arranged in said board.

In a preferred embodiment, a plurality of said optical transmission channels are provided, while said board is further provided with: a semiconductor element at least selected from a memory LSI and a logic LSI; a laser element; and a photo receiving element.

In a preferred embodiment, said optical transmission channel is an optical fiber.

In an embodiment, an optical module comprises: a board composed of a material containing resin; circuit patterns formed on said board and including a plurality of wirings; and an optical waveguide arranged between the wirings of said circuit patterns so as to substantially contact with said wirings when viewed from the above of said board.

In an example, a data processing apparatus according to the present invention comprises: an above-mentioned board with built-in optical transmission channel; and a semiconductor element mounted on said board with built-in optical transmission channel.

Embodiment 3

FIG. **21** is a perspective view schematically showing the configuration of an optical transmission channel board according to Embodiment 3.

As shown in FIG. **21**, the optical transmission channel board **200** of Embodiment 3 comprises: a board **110** composed of a material containing resin; a plurality of grooves **122** formed in the surface of the board **110**; and optical fibers **120** a portion of each of which is embedded in each groove **122**. Circuit patterns (not shown) including a plurality of wirings are formed on the board **110**. In the configuration of Embodiment 3, apart of the circuit patterns and the grooves **122** into which the optical fibers **120** are embedded are formed in self-conformity with each other. This self-conformal formation is described later in further detail in a fabrication method for the optical transmission channel board **200**.

The optical transmission channels of the present invention are optical fibers **120** in Embodiment 3, and hence Embodiment 3 is described for the case of optical fibers. However, an “optical transmission channel” in the present specification indicates a line-shaped member capable of transmitting light.

In Embodiment 3, the board **110** is composed of a composite material containing resin and inorganic filler. The depth of the groove **122** formed in the board **110** is 1 μm through 5 mm or the like. Thickness of the board **110** is ½ or more of the radius of the optical fiber **120**. An optical element **130** is mounted on the optical transmission channel board **100** shown in FIG. **21**. The optical element **130** is optically connected to the optical fibers **120**. The optical element **130** is electrically connected to a part of the circuit patterns (not shown) with reference to a marker (an optical element marker, hereafter) which is formed in conformity with the grooves **122** serving as mounting sections for the optical fibers **120** and which is used for positioning the optical element. The optical element marker is not illustrated, but typically composed of positioning reference planes **1103***a*, **1103***b*, and **1103***c* shown in FIG. **50** illustrating the prior art.

The optical element **130** is a laser element such as a semiconductor laser, or a photo receiving element such as a photo-diode. In Embodiment 3, the optical element **130** is arranged above the optical fibers **120**. The phrase “arranged above an optical transmission channel” according to the present invention includes the state “arranged such as to substantially contact with the top of an optical transmission channel”.

In Embodiment 3, an example of the electrically conductive material according to the present invention which constitutes the board **110** serving as an example of the retention board of the present invention is a composite material containing resin (such as a thermosetting resin and a thermoplastic resin) and inorganic filler. In this embodiment, a thermosetting resin is used as the resin for the composite material. Without using inorganic filler, the board **110** may be composed solely of thermosetting resin. The thermosetting resin is an epoxy resin or the like. When added, the inorganic filler is Al_2O_3, SiO_2, MgO, BN, AlN, or the like. The addition of inorganic filler permits the control of various physical properties (such as the thermal expansion coefficient). Thus, the board **10** is preferably composed of such a composite material containing inorganic filler. In Embodiment 3, inorganic filler of 100 weight units or more (preferably 140-180 weight units) is contained relative to the thermosetting resin of 100 weight units.

The role of inorganic filler is as follows. When Al_2O_3, BN, or AlN is added as inorganic filler, the thermal conductivity of the board **10** is improved. Further, when an appropriate inorganic filler is selected, the thermal expansion coefficient can be adjusted. In case that the thermal expansion coefficient is rather increased by the resin component, the addition of SiO_2, AlN, or the like can decrease the thermal expansion coefficient. In an appropriate case, when MgO is added, the thermal conductivity is improved while the thermal expansion coefficient is increased. Further, when Si_2O (especially, amorphous SiO_2) is added, the thermal expansion coefficient is decreased while the dielectric constant is reduced.

A fabrication method for an optical transmission channel board according to Embodiment 3 is described below.

The optical transmission channel board **200** of Embodiment 3 is fabricated using a transfer method. More specifically, a metal layer formed on a supporting board is patterned so that circuit patterns are formed that include: wirings for constituting grooves; wirings used as an electric circuit; and wirings used as an optical element marker. Then, a material containing resin is deposited on the supporting board so as to cover the circuit patterns. The material including this deposited resin constitutes a board **110**.

Then, the supporting board is removed so that the circuit patterns are exposed on the surface of the board **110**. Then, a part of the circuit patterns (wirings for constituting the grooves) are removed so that the grooves **122** are formed in the surface of the board **110**. Then, optical fibers **120** are arranged into the grooves **122**. After that, an optical element **130** is mounted with reference to the optical element marker so that an optical transmission channel board **200** of Embodiment 3 is obtained.

As such, the circuit patterns **115** and the grooves **122** are formed in conformity. Further, a part of the circuit patterns are used as an optical element marker. This configuration permits automatic position adjustment with the optical fibers **120** optically connected to the optical element **130**.

Thus, in comparison with the prior art case of FIG. **50** where the circuit patterns (including the position reference planes **1103***a*, **1103***b*, and **1103***c*) and the mounting sections (guide grooves **1104**) for optical fibers are formed separately, alignment is achieved with self-conformity in Embodiment 3.

This resolves the problem of centering, and permits optical connection between the optical element **30** and the optical fibers **20**. In a possible case that a centering process is to be performed in the optical transmission channel board **200** of Embodiment 3 in order to further improve the optical connection, rough centering has already been achieved with a precision better than that of the prior art configuration. Thus, fine centering solely is sufficient.

The optical element **130** is a semiconductor laser or the like, and is arranged above the optical fibers **120** in Embodiment 3. The optical element **130** may be a photo receiving element (such as a photo-diode). In Embodiment 3, the optical element **130** is connected to the wirings **113** via connection members (solder or bumps) **132**. In the example shown in FIG. **24**, the optical element **130** is solely mounted on the board **110**. However, other electronic components (such as semiconductor elements) may be mounted on the board **110**.

The above-mentioned fabrication method for an optical transmission channel board is described below in further detail with reference to FIGS. **22**-**24**.

First, as shown in FIG. **22**(*a*), a carrier sheet (transfer formation material) **140** on which a metal layer **142** is formed is prepared. The metal layer **142** is composed of copper or the like. The carrier sheet **140** serving as an example of the supporting board of the present invention is composed of a metallic foil (a copper or aluminum foil), a resin sheet, or the like.

Then, as shown in FIG. **22**(*b*), a mask **150** corresponding to the circuit patterns is arranged above the metal layer **142**. Then, the metal layer **142** is etched. When the mask **150** is removed after the etching, circuit patterns **115** are formed as shown in FIG. **22**(*c*). The circuit patterns **115** include: wiring portions used as a plurality of the wirings **113**; groove portions (groove-use wirings) **112** to be used as the grooves **122**; and wiring portions serving as an optical element marker (optical element marker wirings).

Then, as shown in FIG. **22**(*d*), a material containing resin is deposited on the carrier sheet (supporting board) **140** so as to cover the circuit patterns **115**. This deposited material containing resin constitutes a board **110** serving as an example of a retention board of the present invention.

Then, as shown in FIG. **23**(*a*), the board **110** composed of resin is reversed. Then, the carrier sheet **140** is removed. As a result, the circuit patterns **115** including the groove-use wirings **112**, the wirings **113**, and the optical element marker wirings are exposed on the surface of the board **110**. At this time, the step of embedding the circuit patterns **115** in the board **110** which corresponds to a first step of the present invention is completed. Then, the circuit patterns **115** on the carrier sheet **140** are separated so that the transfer is completed. The board **110** may be reversed after the removal of the carrier sheet **140**.

Then, as shown in FIG. **23**(*b*), a mask **151** corresponding to the groove-use wirings **112** is arranged on the board **10**. Then, the groove-use wirings **112** are etched and removed so that the grooves **122** are formed in the surface of the board **110** as shown in FIG. **23**(*c*). At that time, the wirings **113** and the optical element marker wirings are covered by the mask **151**. Thus, the groove-use wirings **112** are solely removed during the etching.

Then, when optical fibers **120** are arranged into the grooves **122** as shown in FIG. **23**(*d*), an optical transmission channel board **200** of Embodiment 3 is obtained.

Then, as shown in FIG. **24**, an electronic component (optical element) **130** is mounted on the wirings **113** exposed on the surface of the board **110**, with reference to the optical element marker. As a result, an optical module is obtained. The optical element **130** electrically connected to the wirings **113** can be optically connected to the optical fibers **120** fixed in the grooves **122**.

As described above, in the optical transmission channel board **200** of Embodiment 3, the wirings **112** constituting the grooves **22** for accommodating the optical fibers **120** and the wirings used as an optical element marker are fabricated using the same mask, as shown in FIGS. **22**(*b*) and **22**(*c*). Thus, the discrepancy between the optical element **130** and the optical fibers **120** can easily be suppressed within the tolerance.

In contrast, in the prior art configuration, the formation of an optical element marker formed together with the circuit patterns has been independent of the formation of optical fiber mounting sections. Thus, tolerance discrepancies in these processes have been affected each other, and hence the discrepancy between an optical element **130** and optical fibers **120** has been difficult to be suppressed within the tolerance. Thus, a centering was necessary.

On the other hand, in Embodiment 3, the circuit patterns **115** including the groove-use wirings **112** (grooves **122** used as the mounting sections for the optical fibers **120**) and the optical element marker are formed using the single mask **150**. Thus, conformity is kept through a series of the fabrication processes. Accordingly, what is necessary is to consider solely the tolerance discrepancy in the circuit patterns. Thus, the discrepancy between the optical element **130** and the optical fibers **120** can easily be suppressed within the tolerance.

The optical element marker of Embodiment 3 is a marker for positioning the optical element **130**. However, this marker may serve also as the wirings used as an electric circuit.

A part of circuit patterns used as an electric circuit according to the present invention corresponds to the wirings **113** of Embodiment 3. A part of circuit patterns used as an optical transmission channel marker according to the present invention corresponds to the groove-use wirings **112** of Embodiment 3. However, these wirings may serve also as an optical element marker for positioning an optical element.

A first step of the present invention corresponds to the step shown in FIGS. **22**(*a*)-**22**(*d*), for example. A second step of the present invention corresponds to the step shown in FIGS. **23**(*b*)-**23**(*c*), for example. A third step of the present invention corresponds to the step shown in FIG. **23**(*d*), for example. A fourth step of the present invention corresponds to the step shown in FIG. **24**, for example. As shown in FIG. **22**(*a*)-**22**(*d*) the first step has been described for the case that resin is deposited such as to cover the circuit patterns **115** fabricated on the supporting board **140** by etching, and that the supporting board **140** is then removed. However, the first step of the present invention is not limited to this. That is, another process may be used as long as wiring patterns can be embedded such as to form the groove-use wirings **112** and a plurality of the wirings **113** on the board **110**.

A mask corresponding to a part of circuit patterns used as an optical transmission channel marker of the present invention corresponds to the mask **151** shown in FIG. **23**(*b*) of Embodiment 3, for example. The mask **151** covers the entire surfaces of the board **110** and a plurality of the wirings **113** except for the portion serving as the groove-use wirings **112**. However, it is sufficient that the portion of a plurality of the wirings **113** is covered. That is, a part of the surface of the board **110** need not be covered.

FIG. **25** is a diagram illustrating the detail of a configuration of Embodiment 3. Part of the optical fiber **120** is located in the groove **122**. The height h of the optical fiber **120** relative to the board **110** surface is 90 μm. The depth d of the groove **122** is 32 μm. The width w of the groove **122** is 111 μm. Depending on the dimensions and the type of the optical fibers **120**, dimensions of 1 μm can be sufficient for the attaching of the optical fibers **120** in some cases. According to the configuration of Embodiment 3, the optical

fibers **120** are embedded (built) in the board **110**. Thus, the optical fibers **120** can easily be arranged by using the grooves **122** as a guide, rather than by placing the optical fibers **120** on the board plane.

The optical element **130** and the optical fiber **120** can be optically connected, for example, as shown in the schematic sectional view of FIG. **26**. That is, as shown in FIG. **26**, a reflection surface (inclined surface) **111** is formed in a part of the board **110**. Then, optical connection by light (optical signals) **125** is achieved between the optical element **130** and the optical fiber **120** via the reflection surface **111**. In an example, the reflection surface **111** is obtained by fabricating an inclined surface in the board **110** and then forming a metal layer (such as an Au layer) on the surface of the inclined surface. Alternatively, an optical component (mirror) having a reflection surface **111** may be placed on the board **110**.

Alternatively, as shown in the schematic sectional view of FIG. **27**, an end face **121** of the optical fiber **120** may be cut aslant (such as a 45° cut) so that light **125** should be reflected in the end face **121**. As a result, optical connection is achieved between the optical element **130** and the optical fiber **120**. In the configuration shown in FIGS. **26** and **27**, a transparent medium may be present in the path of the light **125** between the optical element **130** and the optical fiber **120**. The transparent medium may be air, glass, transparent resin, or the like. Similarly to Embodiments 1 and 2, the transparent resin indicates a material permitting optical connection between the optical element **130** and the optical fiber **120**, and capable of transmitting light of a wavelength of 850 nm, 1330 nm, and 1550 nm or the like. More specifically, the transparent resin may be polyimide, epoxy aramid, or the like. Alternatively, an optical component (such as a lens) may be arranged between the optical element **130** and the optical fiber **120**.

When the optical element **130** is mounted on a portion corresponding to the wirings **113** of the circuit patterns, pad sections may be formed in the wirings **113** so that the pad sections may be connected to the element terminals of the optical element **130** by wire bonding. Nevertheless, such wire bonding connection is disadvantageous in high speed characteristics. Thus, as an example shown in FIG. **24**, the connection between the optical element **130** and the wirings **113** is preferably realized by flip chip mounting or the like using connection members (such as bumps and solder balls) **132**. In this case, lands are formed in the portions of the wirings **113** with which the connection members **132** contact.

As shown in FIG. **28**, the optical fibers **120** may be optically connected to optical elements within an MCM (multi-chip module) **135**, in place of a single optical element **130**. As shown in FIG. **28**, a plurality of electronic components **133***a*; **133***b*, and **133***c* are mounted on an interposer **134** so that an MCM **135** is constructed. At least one of the electronic components **133***a*, **133***b*, and **133***c* is an optical element. All the electronic components **133***a*, **133***b*, and **133***c* may be laser elements (semiconductor lasers), or may be photo receiving elements (photo-diodes). Alternatively, they may be a combination of laser elements and photo receiving elements. In an example, an opening is formed in a part of the interposer **134** corresponding to the optical path between the optical elements and the optical fibers. An optical component (such as a lens) may be arranged in the position of the opening. The electronic components **133***a* and **133***b* composed of optical elements may be mounted on the back side of the interposer **134**.

In the prior art, position adjustment has been necessary between the grooves **122**, the interposer **134**, and the electronic components **133***a*, **133***b*, and **133***c* corresponding to the optical fibers **120**. However, according to the fabrication method of Embodiment 3, the positions of the optical element marker and the grooves **122** are formed in self-conformity using a single mask. This simplifies the position adjustment between the interposer **134** on the wirings **113** and the optical fibers **120** in the grooves **122**, and hence simplifies the centering process in comparison with the prior art.

In the optical transmission channel board **200** of Embodiment 3, the circuit patterns **115** including the wirings **113** with the groove-use wirings **112** are easily formed by a transfer method. Thus, even electronic components other than optical elements (semiconductor elements) can be mounted similarly to the case of a typical printed circuit board. FIG. **29** shows an optical module in which electronic components **131** (**131***a*, **131***b*, **131***c*, **131***d*, and **131***e*) in addition to the optical elements **130***a* and **130***b* are mounted on an optical transmission channel board **200**. The optical module shown in FIG. **29** can be used as a data processing apparatus. This module is described below in further detail.

The optical element **130***a* is a laser element, and may be a vertical-cavity surface-emitting laser (VCSEL). On the other hand, the optical element **130***b* is a photo receiving element, and may be a photo-diode unit having a plurality of photo-receiving sections. For the simplicity of understanding the configuration of Embodiment 3, grooves **122** are shown without optical fibers **120** to be optically connected to the optical element **130***a*.

A driver IC **131***a* is connected to the optical element **130***a* composed of a laser element. The driver IC **131***a* is connected to an LSI chip (such as a logic LSI like an image processing LSI) **131***b*. The LSI chip **131***b* is connected to a memory chip **131***c*. An optical element **130***b* composed of a photo receiving element is connected to the LSI chip **131***b* via an amplifier (preamplifier) **131***d* and an amplifier **131***e*. These electronic components **131** are mutually connected through the wirings **113** in the circuit patterns **115**.

The problem of centering is resolved by the configuration of the groove-use wirings **112** for accommodating the optical fibers **120** and the optical element marker wirings. Thus, other wirings may be formed on the board **110** separately in a step other than a transfer process (for example, in an independent and later step). However, from the perspective of fabrication procedure, cost, and the like, it is efficient to fabricate other wirings not relevant to the optical element **130** in the same step as that of the circuit patterns **115**, as in the fabrication method of Embodiment 3.

The optical module (data processing apparatus) shown in FIG. **29** can perform optical transmission through the optical fibers **120**. Thus, mass data can be transmitted at a high speed. Further, this module fabricated by the method of Embodiment 3 has a low fabrication cost.

That is, in the prior art, the optical element markers and the optical fiber mounting sections have been fabricated in separate steps. This has caused a larger tolerance discrepancy and hence a higher fabrication cost. In contrast, in the present invention, the circuit patterns **115** including the groove-use wirings **112**, the wirings **113**, and the optical element marker wirings are integrally fabricated first. Then, the grooves **122** used as an optical fiber mounting sections are formed from the groove-use wirings **112**. This reduces the fabrication cost. Thus, the cost can be reduced in optical

modules presently used in optical communications (such as the Internet and telephone). This accelerates the spread of such optical modules.

Further, the cost reduction permits the use of economical optical transmission in within-the-board transmission (level 2) in the communication system apparatus **3000** shown in FIG. **52**. This improves the speed of within-the-board transmission. As such, the present invention is applicable to the bookshelf type communication system apparatus **3000** shown in FIG. **52**. Further, the optical transmission channel board or optical module **1000** of the present invention may be used as a main apparatus such as a next-generation high performance optical I/O module and a data processing apparatus (like an image processing apparatus).

Embodiment 4

Further features and further modifications of the optical transmission channel board **200** of Embodiment 3 are described below with reference to other drawings.

In Embodiment 3 described above, the grooves **122** have been formed by the groove-use wirings **112**. However, the grooves **122** may be fabricated by etching a part of a board **110** in the state shown in FIG. **23**. Nevertheless, when the grooves **122** are solely fabricated, the grooves **122** serving as optical fiber mounting sections and wirings **113** on which the optical element **130** is mounted are fabricated in separate parts.

Thus, in place of the mask **151** shown in FIG. **23**(*b*) of Embodiment 3, a mask is used in which an opening is formed in the middle of the groove-use wiring **112**. That is, in order that the above-mentioned fabrication in separate parts should be avoided, as shown in FIG. **30**(*a*), it is preferable that the portion between a wiring **112'** and a wiring **112'** corresponding to the groove-use wiring **112** included in the circuit patterns **115** of Embodiment 3 is removed so that a groove **122** is formed. In this case, the groove **122** is formed in conformity with the circuit patterns **115**.

A part of a board portion between adjacent ones of said electrode patterns of the present invention is, for example, the portion of the board **110** between the wiring **112'** and the wiring **112'** contained in the circuit patterns **115** shown in FIG. **30**(*a*).

The optical element marker may serve also as the wirings used as an electric circuit, and further may serve also as the wirings used as an optical transmission channel marker.

A part of the circuit patterns used as an optical transmission channel marker of the present invention corresponds to the wirings **112'** of Embodiment 4. The wirings **112'** are lines for defining the groove **122**. Unlike the groove-use wirings **112** (see FIG. **23**) which disappear later, the wirings **112'** remain also in the optical transmission channel board **200** serving as an end product. Thus, the wirings **112'** may serve as wirings for a signal or for power supply, that is, as wirings used as an electric circuit of the present invention. When an optical fiber **120** is mounted, the configuration shown in FIG. **30**(*b*) is obtained. The optical fiber **120** is an insulator. Thus, even when the optical fiber **120** contacts with the wirings **112'**, no problem arises in particular.

The mask corresponding to a part of a retention board of the present invention is the mask used for removing the portion between the wirings **112'** of Embodiment 4, for example. The portions of the wirings **112'** and the wirings **113** need not be covered. That is, sufficient is such a mask that the resin portion between the wirings **112'** is open and that other resin portions are covered.

In Embodiment 4, positioning of the optical fiber **120** is regulated by the edge portions of the two wirings **112'** on the surface side of the board **110**. Thus, as shown in FIG. **30**(*c*), the depth of the groove **122** may be deeper than the embedding position of the wirings **112'**. That is, the optical fiber **120** need not contact with the bottom surface of the groove **122**.

As shown in FIG. **30**(*d*), the depth of the groove **122** and the spacing between the wirings **112'** may be equal to the diameter of the optical fiber **120** so that the optical fiber **120** should not protrude above the surface of the board **110**. The depth of the groove **122** may be further deeper.

Also in Embodiment 3, the size of the groove-use wirings **112** may be changed as described above. In these configurations, the optical fiber **120** does not contact with the bottom surface of the groove **122**, or alternatively the optical fiber **120** does not protrude above the surface of the board **110**.

As shown in FIG. **31**(*a*), the shape of the groove **122** described in Embodiments 3 and 4 may be changed so that the groove edges form a taper. More specifically, the angle θ between a side surface (wall) **122***a* for defining the groove **122** and the surface (upper surface) **110***a* of the board **110** is not limited to 90°, and may be an obtuse angle. In order that the groove **122** having obtuse angles θ, etching is performed from an acute angle direction, for example. When the edges of the groove **122** form a taper as shown in FIG. **31**(*b*), the accuracy in the position adjustment of the center line **127** of the optical fiber **120** is improved by the inclined surfaces of the walls **122***a*.

A Y branching section **123** as shown in FIG. **32** may be formed in the optical fiber **20** on the optical transmission channel board **200** of Embodiments 3 and 4. The use of such an optical fiber **120** having a Y branching section **123** provides an optical module (optical transmission channel board) suitable for wavelength multiplexing. When such an optical fiber **120** having a Y branching section **123** is used, it is sufficient that the groove **122** is formed into a form corresponding thereto, so that the optical fiber **120** is appropriately retained by the groove **122**.

As for the optical connection between the optical element **130** and the optical fiber **120**, a mirror having a reflection surface **111** (see FIG. **26**) may be arranged under the optical element **130** so that optical connection between the optical element **130** and the optical fiber **120** may be performed using the mirror. A stopper for the optical fiber **120** may be arranged so as to position the optical fiber **120**. The stopper is arranged under the optical element **130**, and may be arrange in the groove **122**, for example.

An optical element of the present invention corresponds to the optical element **130** in Embodiments 3 and 4, and is arranged above the optical fiber **120** as shown in FIG. **26**. In case that this optical element is a light emitting element, the optical element **130** is a surface emitting type element (light is emitted from its bottom surface). In place of this surface emitting type element, an edge emitting type element (light is emitted from the end face of the optical element) may be arranged in a direction extended from of the optical fiber **120** (substantially provided on the same plane on which the optical fiber is provided).

FIG. **33** is a side view of an optical transmission channel board employing an edge emitting type element **160**. As shown in FIG. **33**, in order that optical connection is established for the edge emitting type element, the depth of the groove for mounting the optical fiber **120** needs to be adjusted such as to match with the height of the edge emitting type element **160**. In a prior art optical transmission

channel board employing an edge emitting type element, position adjustment has been necessary in the depth direction (perpendicular to the plane of the board **110**) and in a direction parallel to the plane of the board **110**. However, in the fabrication method of Embodiments 3 and 4, position adjustment in the parallel direction is almost unnecessary. This simplifies the centering process, and hence reduces the fabrication cost in comparison with the prior art.

Embodiments 3 and 4 have been described for the case that the optical transmission channel board employs optical fibers. However, in place of the optical fibers **120**, optical waveguides composed of plane waveguides (PLCs) may be used as optical transmission channels. When optical waveguides composed of plane wave guides (PLCs) are used as optical transmission channels, a plurality of grooves formed on the plane waveguide (PLC) side are engaged with a plurality of the grooves **122**. This improves manufacturability. When wirings **13** are formed on the plane waveguide (PLC) side, or when the optical element **130** is mounted on the plane waveguide (PLC) side, fabrication and the centering problem are further simplified. Nevertheless, from the perspective of cost, the use of optical fibers based on the fabrication method of Embodiments 3 and 4 can be advantageous over the use of the optical waveguides composed of plane waveguides (PLCs).

The present invention has been described above with reference to a preferred embodiment. This description is not a limitation, and hence various modifications can be made. For example, in the above-mentioned embodiment, the circuit patterns for arranging the optical element **130** shown in FIG. **24** have also been embedded. However, the step of embedding the circuit patterns for the optical element marker may be omitted.

As described above, a fabrication method for an optical transmission channel board according to the present invention comprises: a step (a) of patterning a metal layer formed on a supporting board and thereby forming circuit patterns including a plurality of wirings; a step (b) of depositing a material containing resin on said supporting board so as to cover said circuit patterns; a step (c) of removing said supporting board and thereby exposing said circuit patterns in the surface of the resin film composed of said material containing resin; a step (d) of removing a part of said circuit patterns and thereby forming a groove in the surface of said resin film; and a step (e) of arranging an optical transmission channel into said groove.

In a preferred embodiment, said step (a) comprises: a step of preparing a supporting board and a metal layer formed on said supporting board; and a step of etching said metal layer using a mask corresponding to the patterns including said circuit patterns.

In a preferred embodiment, said circuit patterns include: a wiring portion serving as a plurality of said wirings; and a groove portion used as said groove.

In an example, said material containing resin is preferably a composite material containing resin and inorganic filler.

In an embodiment, the depth of said groove is 1 μm or more and 5 mm or less.

In an embodiment, in said step (b), said material containing resin is deposited in ½ or more of the thickness of the radius of said optical transmission channel.

In a preferred embodiment, in said step (d), said groove is formed such that the edges of said groove form a taper.

In a preferred embodiment, a step of mounting electronic components electrically connected to said circuit pattern is further performed after said step (e).

In a preferred embodiment, at least one of said the electronic components is at least one optical element of a laser element and a photo receiving element. Said optical element is arranged on or above said optical transmission channel.

In an embodiment, another fabrication method for an optical transmission channel board according to the present invention comprises: a step (a) of patterning a metal layer formed on a supporting board and thereby forming circuit patterns including a plurality of wirings; a step (b) of depositing a material containing resin on said supporting board such as to cover said circuit pattern; a step (c) of removing said supporting board and thereby exposing said circuit pattern in the surface of the resin film composed of said material containing resin; a step (d) of removing the resin present between the wirings of said circuit patterns and thereby forming a groove in the surface of said resin film; and a step (e) of arranging an optical transmission channel into said groove.

In a preferred embodiment, said optical transmission channel is an optical fiber.

In an embodiment, an optical transmission channel board according to the present invention comprises: a board composed of a material containing resin; and circuit patterns formed on said board and including a plurality of wirings. A plurality of grooves are formed in the surface of said board. A portion of an optical transmission channel is embedded in each of a plurality of said grooves.

In a preferred embodiment, said grooves in which said optical transmission channels are embedded and a part of said circuit patterns are formed in self-conformity with each other.

In a preferred embodiment, said optical transmission channel has a Y branching section arranged in said groove.

In a preferred embodiment, the edges of said groove form a taper.

In a preferred embodiment, said board is provided with: a semiconductor element at least selected from a memory LSI and a logic LSI; a laser element; and a photo receiving element.

In a preferred embodiment, said optical transmission channel is an optical fiber.

A data processing apparatus according to the present invention comprises: an above-mentioned optical transmission channel board; and a semiconductor element mounted on said optical transmission channel board.

Embodiment 5

A board with built-in optical transmission channel **300** according to Embodiment 5 of the present invention is described below with reference to FIGS. **34**-**39**. FIG. **34** is a perspective view schematically showing the configuration of the board with built-in optical transmission channel **300** of Embodiment 5.

The board with built-in optical transmission channel **300** of Embodiment 5 comprises: a board **210**; circuit patterns **215** including a plurality of wirings **212** formed on the board **210**; and a plurality of optical transmission channels **220** (**220***a*, **220***b*) embedded in the board **210**. The optical transmission channel **220***a* and the optical transmission channel **220***b* are arranged in different hierarchies in the depth direction **219** of the board **210**. Thus, the optical transmission channels **220** are in multi-layer arrangement. An optical element **230** is arranged above the end portion of each optical transmission channel **220** (**220***a*, **220***b*). A part (wirings **212**) of the circuit patterns **215** formed on the upper

surface of the board **210** are electrically connected to the optical element **230**. A positioning marker (not shown) for the optical element **230** similar to the positioning reference planes **103***a*-**103***c* described in FIG. **50** is formed on the board **210**. The circuit patterns **215** includes also the positioning marker. The thickness direction of the board according to the present invention corresponds to the depth direction **219** of the board **210**, for example.

In Embodiment 5, grooves **222** are formed between the wirings **212**, while optical transmission channels **220** are arranged in the grooves **222**. In the example shown in FIG. **34**, the grooves **222** are shown that correspond to the optical fibers (optical waveguides) **220***a* in the upper row. However, other grooves may also be present that correspond to the optical fibers (optical waveguides) **220***b* in the lower row. This example shows a two stage configuration (**220***a*, **220***b*). However, a three or more stage configuration may be used. The optical transmission channels **220** in Embodiment 5 are optical fibers, and hence Embodiment 5 is described for the case of optical fibers.

When viewed from the above of the board **210** (viewed from the normal direction of the board **210**) **212**, the optical fibers **220** are arranged between the wirings **212** and adhered with adhesives or the like, such as to contact with the wirings **212**. As described above, in Embodiment 5, the optical fibers **220** are arranged in the grooves **222** formed between the wirings **212**, and are built in the board **210**. In other words, the grooves **222** formed between the wirings **212** serves as mounting sections for the optical fibers **220**. In Embodiment 5, the uppermost portions of the optical fibers **220** are substantially in plane with the upper surface (that is, the upper surface of the wirings **212**) of the circuit patterns **215**.

An optical element **230** is mounted on the board with built-in optical transmission channel (board with built-in optical fiber) **300** shown in FIG. **34**. This optical element is electrically connected to the wirings **212**, and optically connected to the optical fibers **220** (**220***a*, **220***b*). In Embodiment 5, the optical element **230** is arranged above the optical fibers **220** (**220***a*, **220***b*) or alternatively such as to substantially contact with the optical fibers **220***a* in the uppermost row.

The optical element **230** is a laser element such as a semiconductor laser, or a photo receiving element such as a photo-diode. In this example, the optical element **230** is a vertical-cavity surface-emitting laser (VCSEL). The light-emitting surface of the optical element (VCSEL) **230** is opposing to the surface of the board **210**. The light-emitting surface has a plurality of light emission points. In case that the optical element **230** is a photo receiving element, the photo receiving surface of the optical element **230** is opposing to the surface of the board **210**. The photo receiving surface has a plurality of photo reception points.

The board **210** is composed of a material containing resin. In Embodiment 5, the material constituting the board **210** is composed of a composite material containing resin (such as a thermosetting resin and a thermoplastic resin) and inorganic filler. In this embodiment, a thermosetting resin is used as the resin for the composite material.

Without using inorganic filler, the board **210** may be composed solely of thermosetting resin. The thermosetting resin is an epoxy resin or the like. When added, the inorganic filler is Al_2O_3, SiO_2, MgO, BN, AlN, or the like. The addition of inorganic filler permits the control of various physical properties (such as the thermal expansion coefficient). Thus, the board **210** is preferably composed of such a composite material containing inorganic filler. In Embodiment 5, inorganic filler of 100 weight units or more (preferably 140-180 weight units) is contained relative to the thermosetting resin of 100 weight units.

The role of inorganic filler is as follows. When Al_2O_3, BN, or AlN is added as inorganic filler, the thermal conductivity of the board **210** is improved.

Further, when an appropriate inorganic filler is selected, the thermal expansion coefficient can be adjusted. In case that the thermal expansion coefficient is rather increased by the resin component, the addition of SiO_2, AlN, or the like can decrease the thermal expansion coefficient.

In an appropriate case, when MgO is added, the thermal conductivity is improved while the thermal expansion coefficient is increased.

Further, when Si_2O (especially, amorphous SiO_2) is added, the thermal expansion coefficient is decreased while the dielectric constant is reduced.

FIG. **35** is a sectional view schematically showing an example of the configuration of the board with built-in optical transmission channel (board with built-in optical fiber) **300** of Embodiment 5.

The board with built-in optical transmission channel **300** shown in FIG. **35** is formed from a board **210** obtained by stacking a sub-board **210***a* with a sub-board **210***b*. Grooves **222** are formed both in the sub-boards **210***a* and **210***b*. Optical fibers **220** (**220***a*, **220***b*) are arranged in the grooves **222**. Guide walls **218** formed by guide layers **216** and **217** are arranged under the wirings **212** included in the circuit patterns **215**. The optical fibers **220** are arranged between the guide walls **218**. A gap between each of the right and left guide walls **218** and the optical fiber **220** is preferably 0.1 μm or less, specifically.

Guiding means of the present invention corresponds to the guide wall **218**, for example.

The wirings **212** on the sub-board **210***a* are electrically connected to the optical element **230**. In this example, wirings **213** other than the wirings **212** are also formed in the circuit patterns **215**. An electronic components (such as a semiconductor element) **231** is electrically connected to the wiring **213** on the sub-board **210***a*.

The electronic component **231** is connected to the wirings **213** via solder balls **232**. The wirings **213** in the sub-board **210***b* can be connected to the circuit patterns **215** on the sub-board **210***a* through via holes (not shown). In this case, the board **210** composed of the sub-boards **210***a* and **210***b* can be used as a multi-layered board. The wirings **213** on the sub-board **210***b* may be omitted.

In the board with built-in optical transmission channel **300** of Embodiment 5, the optical transmission channels (optical fibers) **220** are accommodated and fixed in the grooves **222**. Thus, the optical element **230** can easily be positioned with the optical fibers **220** (**220***a*, **220***b*). This is because the grooves **222** are formed with reference to a part (**212**) of the circuit patterns **215**, and because the optical element **230** can also be aligned with the reference. In the configuration shown in FIG. **35**, the sub-boards **210***a* and **210***b* are fabricated by stacking. Thus, a multi-stage optical transmission channel board having two, three, or more stages can be fabricated easily. At the same time, a multi-layer electricity wiring board can be fabricated.

The optical element **230** and the optical fibers **220** can be optically connected to each other, for example, as shown in FIG. **36** which is a schematic partial sectional view of the configuration of FIG. **35**. That is, as shown in FIG. **36**, a reflection surface (inclined surface) **211** is formed in a part of the board **210**. Then, optical connection by light (optical signals) **225** is achieved between the optical element **230** and the optical fibers **220** via the reflection surface **211**. In

an example, the reflection surface **211** is obtained by fabricating an inclined surface in the board **210** and then forming a metal layer (such as an Au layer) in the surface of the inclined surface. Alternatively, an optical component (mirror) having a reflection surface **211** may be placed on the board **210**.

More specifically, the reflection surface **211** can be formed as follows. In an example, an inclined surface is fabricated in advance by etching, machining, or the like. Then, a new step of forming a metal layer (such as an Au layer) on the surface of the inclined surface is added before the step of FIG. **41**(*c*) described later or between the steps of FIGS. **45**(*a*)-**45**(*c*), or alternatively performed at the same time as these steps.

Alternatively, as shown in FIG. **37** which is a schematic partial sectional view of the configuration of FIG. **35**, an end face **221** of the optical fiber **220** is cut aslant (such as a 45° cut). Then, light **225** is reflected in the end face **221** so that optical connection is achieved between the optical element **230** and the optical fiber **220**. In this case, as shown in this figure, the end face **221** of the optical fiber **220** is in an opposite direction relative to the upper surface of the board **210** where the optical element **230** is mounted.

In the configuration shown in FIGS. **36** and **37**, the optical element **230** and the optional fiber **220** are closely contacted, but a transparent medium may be present in the path of the light **225** between the optical element **230** and the optical fiber **220**. The transparent medium may be air, glass, transparent resin, or the like. Similarly to Embodiments 1-4, the transparent resin is a material permitting optical connection between the optical element **230** and the optical fiber **220** and transmitting light having a wavelength of 850 nm, 1330 nm, and 1550 nm, or the like. More specifically, the transparent resin may be polyimide, epoxy aramid, or the like. Alternatively, an optical component (such as a lens) may be arranged between the optical element **230** and the optical fiber **220**.

In the case of multi-stage optical transmission channels, the configuration is as shown in FIG. **38** which is a schematic sectional view showing the configuration of FIG. **35**. Here, the optical fibers **220***a* in the upper row are optically connected to the optical element **230** by light **225***a*. On the other hand, the optical fibers **220***b* in the lower row is optically connected to the optical element **230** by light **225***b*. In this case, as shown in the figure, the end faces **221***a* and **221***b* of the optical fibers **220** are in an opposite direction relative to the upper surface of the board **210** where the optical element **230** is mounted.

The end faces **221***a* and **221***b* of the optical fibers **220** can be positioned with a sufficient accuracy as follows. In an example shown in FIG. **42**(*b*), when the patterns **214** on the lower layer sub-board **210***b* are optically aligned with the patterns **214** on the upper sub-board **210***a*, accurate stacking is achieved. In another example shown in FIG. **46**, when the upper and lower optical fibers **220***a* and **220***b* are closely adhered with each other in advance, accurate positioning is achieved in the end faces **221***a* and **221***b*.

Further, as shown in FIG. **39** which is a schematic sectional view showing the configuration of FIG. **35**, in place of the optical connection with the optical element **230**, optical connection between the optical fibers **220***a* in the upper row and the optical fibers **220***b* in the lower row is also achieved.

Although detail is described later, in the fabrication of the board with built-in optical transmission channel (board with built-in optical fiber) **300** of Embodiment 5, prepared are sub-boards **210***a* and **210***b* on the surface of each of which circuit patterns **215** including a plurality of wirings **212** are formed and in each of which optical transmission channels (optical fibers) **220** are arranged in the grooves **222** formed between the wirings **212**. Then, the sub-boards **210***a* and **210***b* are stacked with each other. Each of the sub-boards **210***a* and **210***b* can be fabricated using a transfer method. More specifically, a metal layer formed on a supporting board (see numeral **240** in FIG. **40**) is patterned so that the circuit patterns **215** including a plurality of the wirings **212** are formed. Then, optical fibers **220** (**220***a* or **220***b*) are arranged between the wirings **212** of the circuit patterns **215**. After that, a material containing resin is deposited on the supporting board so as to cover the circuit patterns **215** and the optical fibers **220** (**220***a* or **220***b*). Then, when the supporting board is removed, the circuit patterns **215** are exposed in the surface so that each of the sub-boards **210***a* and **210***b* is obtained.

A fabrication method for the board with built-in optical fiber **300** according to Embodiment 5 of the present invention is described below in detail.

First, as shown in FIG. **40**(*a*), a carrier sheet (transfer formation material) **240** on which a metal layer **242** is formed is prepared. The metal layer **242** is composed of copper or the like. The carrier sheet **240** serves as a supporting board, and is composed of a metallic foil (a copper or aluminum foil) or a resin sheet. The thickness of the metal layer **242** and the thickness of the carrier sheet **240** are approximately 3-50 μm and approximately 25-200 μm, respectively.

Then, as shown in FIG. **40**(*b*), a mask **250** corresponding to the circuit patterns **215** is arranged above the metal layer **242**, and then the metal layer **242** is etched. As a result, as shown in FIG. **40**(*c*), the circuit patterns **215** including the wirings **212** are formed. In the example shown in the figure, in addition to the wirings **212** located in the surrounding portion of the optical fibers **220**, other wirings **213** are shown as wirings included in the circuit patterns **215**.

After the patterning by the above-mentioned etching, walls used as a guide for arranging the optical fibers **220** are formed in at least a part of the circuit patterns **215**. In Embodiment 5, the guide walls are formed on the wirings **212**.

More specifically, as shown in FIG. **40**(*c*), the mask **251** having an opening in the portion of the wirings **212** is arranged above the carrier sheet **240**. Then, as shown in FIG. **40**(*d*), a layer (guide layer) **216** for constituting the guide walls is deposited on the wirings **212**. The guide layer **216** is composed of metal or the like and formed by sputtering. In place of the sputtering, vapor deposition, plating, a deposition method, or the like may be used. In Embodiment 5, the reason why the guide layer **216** is formed by sputtering is that this method has good shape reproducibility.

In case that the height of the guide walls for supporting the optical fibers **220** is insufficient even after the guide layer **216** is deposited, a mask **252** is arranged above the guide layer **216** as shown in FIG. **41**(*a*), and then another guide layer **217** is deposited on the guide layer **216** serving as a base. The mask **252** may be the same as the previous mask **251**. The material constituting the guide layer **217** may be the same as, or different from, the material constituting the guide layer **216**. The material constituting the guide layers **216** and **217** is not limited to a metal, and may be another material (such as a resin).

As such, as shown in FIG. **41**(*b*), the guide walls **218** formed by the guide layer **216** and the guide layer **217** are fabricated on the wirings **212**. The guide walls **218** form grooves **222** (optical fiber mounting sections) in which

optical fibers **220** are mounted. In Embodiment 5, the sum of the thickness values of the wiring **212** and the guide wall **218** (guide layers **216** and **217**) is greater than the radius of the optical fiber **220** arranged between the guide walls **218**. This simplifies fabrication and improves accuracy.

Then, as shown in FIG. **41**(*c*), the optical fibers **220** are arranged between the guide walls **218** (between the wirings **212**). In other words, the optical fibers **220** are arranged into the grooves **222** formed between the guide walls **218** (or the wirings **212**). In Embodiment 5, the optical fibers **220** are arranged such as to contact with the carrier sheet (supporting board) **240**. Further, the optical fibers **220** are arranged between the wirings **212** such as to contact with the guide walls **218**.

Then, as shown in FIG. **41**(*d*), the material containing resin is deposited on the carrier sheet **240** so that a sub-board (insulating board) **210***a* is formed. This deposition is performed such that the circuit patterns **215** and the optical fibers **220** are covered. That is, the material constituting the sub-board **210***a* covers: the circuit patterns **215** including the wirings **212** and **213**; the guide walls **218**; and the optical fibers **220**.

Then, as shown in FIG. **42**(*a*), the sub-board **210***a* is reversed, and then the carrier sheet **240** is removed. That is, the circuit patterns **215** on the carrier sheet **240** are separated so that the transfer is completed. Alternatively, the sub-board **210***a* may be reversed after the removal of the carrier sheet **240**. According to the same fabrication process, the sub-board **210***b* is also fabricated. Then, the sub-board **210***a* and the sub-board **210***b* are stacked with each other, so that a board with built-in optical transmission channel **300** of Embodiment 5 is obtained as shown in FIG. **42**(*b*).

These steps shown in FIGS. **40**, **41**, and **42**(*a*) correspond substantially to the steps of FIGS. **2**, **3**, and **4**(*a*) described In Embodiment 1. That is, each of the sub-boards **210***a* and **210***b* can be fabricated by the fabrication method for an optical transmission channel board of Embodiment 1.

On completion of the board with built-in optical transmission channel **300**, an optical element **230** is mounted on the wirings **212** of the sub-board **210***a*, while an electronic component **231** is mounted on the wirings **213**. As a result, the configuration shown in FIG. **35** is obtained.

The optical element **230** is a semiconductor laser or the like. In Embodiment 5, this optical element is arranged above the optical fibers **220**, or alternatively such as to substantially contact with the optical fibers **220**. The optical element [? **30**?] **230** may be a photo receiving element (such as a photo-diode) The electronic component **231** mounted on the portion of the wirings **213** of the circuit patterns **215** is a semiconductor element (such as a logic LSI). The electronic component (semiconductor element) **231** is electrically connected to the wirings **213** through solder balls **232**. A first step of the present invention corresponds to the step shown in FIGS. **40**(*a*)-**40**(*c*), for example. A second step of the present invention corresponds to the step shown in FIGS. **40**(*d*)-**41**(*b*), for example. A third step of the present invention corresponds to the step shown in FIGS. **41**(*c*)-**42**(*a*), for example. A fourth step of the present invention corresponds to the step shown in FIG. **42**(*b*), for example.

The step shown in FIGS. **40**(*a*)-**40**(*c*) is described for an exemplary case that "all of the circuit patterns are formed" in the first step of the present invention. The step shown in FIGS. **40**(*d*)-**41**(*b*) is described for an exemplary case that "the guiding means is formed using said circuit patterns" in the second step of the present invention.

In the fabrication method of Embodiment 5, in the state shown in FIG. **41**(*d*), the circuit patterns **215** and the optical fibers **220** contact with the carrier sheet **240**. Thus, in the state shown in FIG. **42**(*a*), the upper surface of the circuit patterns **215** and the uppermost portions of the optical fibers **220** are substantially in plane. Further, the resin surface (accurately, the surface composed of a composite material) of the sub-board **210***a*, the upper surface of the circuit patterns **215**, and the uppermost portions of the optical fibers **220** are substantially in plane. Thus, the sub-board **210***a* and the sub-board **210***b* are easily stacked with each other in the step shown in FIG. **42**(*b*).

Further, according to the fabrication method of Embodiment 5, the optical fibers **220** can easily be embedded (built) in the board **210** (or the sub-boards **210***a* and **210***b*). Thus, the optical fibers **220** are protected more appropriately in comparison with the case that the optical fibers **220** are formed on the surface of the board **210**.

When the optical element **230** is mounted on the portion of the wirings **212** of the circuit patterns **215**, pad sections may be formed in the wirings **212** so that the pad sections may be connected to the element terminals of the optical element **230** by wire bonding. Nevertheless, the wire bonding connection is disadvantageous in high-speed characteristics.

Accordingly, as shown in FIG. **43**, the connection between the optical element **230** and the wirings **212** is preferably achieved by flip chip mounting or the like using connection members (such as bumps and solder balls) **232**. In this case, lands are formed in the portions of the wirings **212** contacting with the connection members **232**.

As shown in FIG. **44**, the optical fibers **220** may be optically connected to optical elements within an MCM (multi-chip module) **235**, in place of a single optical element **230**.

In this example, a plurality of electronic components **233***a* and **233***b* are mounted on an interposer **234** so that an MCM **235** is constructed. At least one of the electronic components **233***a* and **233***b* is an optical element. Both of the electronic components **233***a* and **233***b* may be laser elements (semiconductor lasers), or alternatively photo receiving elements (photo-diodes). Alternatively, these electronic components may be a combination of a laser element and a photo receiving element. An opening is formed in the part of the interposer **234** corresponding to the optical path between the optical element and the optical fiber. An optical component (such as a lens) may be arranged in the position of the opening. The optical elements **233***a* and **233***b* may be mounted on the back side of the interposer **234**.

A board with built-in optical transmission channel **300** according to Embodiment 5 of the present invention may be fabricated in alternative steps shown in FIGS. **45**(*a*)-**45**(*c*). This method is described below in detail.

First, starting from the state shown in FIG. **40**(*a*), guide layers **216** and **217** are stacked on a metal layer **242** so that the state shown in FIG. **45**(*a*) is achieved. Then, as shown in FIG. **45**(*b*), using a mask **253** for defining the shape of grooves **222**, these layers (**217**, **216**, **242**) are etched so that grooves **222** are formed.

Then, etching is performed using a predetermined mask, so that guide walls **218** and circuit patterns **215** (including wirings **212** and wirings **213**) are formed as shown in FIG. **45**(*c*). FIG. **45**(*c*) is similar to FIG. **41**(*b*). Thus, after the steps following FIG. **41**(*c*) are performed, a board with built-in optical transmission channel **300** shown in FIGS. **42**(*b*) and **35** is obtained.

"A first step of forming a part of circuit patterns" and "a second step of forming together with at least a part of the circuit patterns" according to the present invention corre-

spond to the step shown in FIG. **45**(*b*) as an example, and are performed substantially at the same time.

In this example, the grooves **222** have been formed first, and then the circuit patterns **215** has been formed. However, in the state of FIG. **45**(*b*), the grooves **222** and the circuit patterns **215** may be simultaneously formed (in the same step) using a mask corresponding to the circuit patterns **215**. Then, unnecessary portions of the guide layers **216** and **217** may be removed so that the guide wall **218** may be fabricated as shown in FIG. **45**(*c*). At that time, unnecessary portions of the guide layers **216** and **217** need not be removed, and may be kept embedded in the board **210**. As described above, these two guide layers **216** and **217** need not be used. Instead, the guide layers **216** and **217** may be formed from the same material as a single guide layer.

Another fabrication method may be used in which the depth of the groove **222** is increased (that is, the height of the guide wall **218** is increased) so that two optical fibers **220** are inserted in the groove **222** in the vertical direction. As a result, a board with built-in optical transmission channel **300** shown in FIG. **46** is obtained. This another fabrication method according to an embodiment of the present invention, together with a board with built-in optical transmission channel according to an embodiment of the present invention, is described below with reference mainly to FIG. **46**.

The difference of the fabrication method shown in FIG. **46** from the previous one mentioned above is that a plurality of optical fibers **220***a* and **220***b* are stacked between the guide walls **218** in the thickness direction of the board **210**. By virtue of this, in the board with built-in optical transmission channel **300** shown in FIG. **46**, the distance to the optical element is reduced so that the optical loss is advantageously reduced. FIG. **46** shows the case that two optical fibers are stacked and embedded. However, the present invention is not limited to this. Three or more optical fibers may be stacked. In this case, the height of the guide wall **218** is adjusted appropriately.

FIG. **47** is a sectional view schematically showing another configuration of a board with built-in optical transmission channel (optical module) **300** of Embodiment 5.

The board with built-in optical transmission channel **300** shown in FIG. **47** serves as a multi-layered circuit board as well as a multi-stage optical transmission channel board. Optical transmission channels (optical fibers) **220** extended from the board **310** are connected to an optical connector **227**. Each wiring layer **212** or **213** in the board **210** is electrically connected through interlayer connection members (via holes) **236**. An optical element (VCSEL) **230** and a semiconductor element (LSI chip) **231** are mounted on one surface of the board **210** through connection members **232**. An electric input and output section (electric I/O) **237** is formed in the other surface of the board **210**. As described above, a transparent medium (such as air, glass, transparent resin, or an optical member) is present between the optical fibers **220** (more specifically, end faces **221** of the optical fibers **220**) and the optical element **230**.

In the board with built-in optical transmission channel **300** of Embodiment 5, other wirings (such as the wiring layer **213**) can be formed together with the wirings **212** easily by a transfer method. Thus, electronic components other than optical elements (semiconductor elements) can be mounted similarly to the case of a typical printed circuit board. FIG. **48** shows an optical module in which electronic components **231** (**231***a*, **231***b*, **231***c*, **231***d*, **231***e*) in addition to optical elements **230***a* and **230***b* are mounted on a board with built-in optical transmission channel **300**. The board with built-in optical transmission channel (optical module) shown in FIG. **48** can be used as a data processing apparatus. This module is described below in further detail.

The optical element **230***a* is a laser element and more specifically a vertical-cavity surface-emitting laser (VCSEL) On the other hand, the optical element **230***b* is a photo receiving element and more specifically a photo-diode having a plurality of photo-receiving sections. For the simplicity of understanding the configuration of Embodiment 5, grooves **222** are shown without optical fibers **220** in the uppermost row optically connected to the optical element **230***a*. The wirings **212** are also omitted.

A driver IC **231***a* is connected to the laser element **230***a*. The driver IC **231***a* is connected to an LSI chip (such as a logic LSI like an image processing LSI) **231***b*. The LSI chip **231***b* is connected to a memory chip **231***c*. A photo receiving element **230***b* is connected to the LSI chip **231***b* via an amplifier (preamplifier) **231***d* and an amplifier **231***e*. These electronic components **231** are mutually connected through the wirings **213** in the circuit patterns **215**. The optical fibers **220** in the configuration shown in FIG. **48** can also be connected to the optical connector **227** as shown in FIG. **47**.

The wirings **213** may be fabricated on the board **210** in a step other than the transfer process (such as in a separate and later step). Nevertheless, from the perspective of fabrication procedure, cost, and the like, it is efficient to fabricate the wirings **213** in the same step as the wirings **212**, as in the fabrication method of Embodiment 5.

The optical module (data processing apparatus) **300** shown in FIG. **48** can perform optical transmission through the optical fibers **220**. Thus, mass data can be transmitted at a high speed. Further, the method of Embodiment 5 allows such an optical module (data processing apparatus) **300** to be fabricated in a simple process. This reduces the fabrication cost. Thus, the cost can be reduced in optical modules presently used in optical communications (such as the Internet and telephone). This accelerates the spread of such optical modules.

Further, the cost reduction permits the use of economical optical transmission in within-the-board transmission (level 2) in the communication system apparatus **3000** shown in FIG. **52**. This improves the speed of within-the-board transmission. As such, the present invention is applicable to the bookshelf type communication system apparatus **3000** shown in FIG. **52**. Further, the optical transmission channel board or optical module **100** of the present invention may be used as a main apparatus such as a next-generation high performance optical I/O module and a data processing apparatus (like an image processing apparatus).

In the board with built-in optical transmission channel **300** of Embodiment 5, the optical fibers **220** are embedded in the board **210**. Thus, even in case that the optical fibers **220** have a Y branching section **23** as shown in FIG. **49** and hence are fragile, the present embedding enforces the optical fibers **220**. More specifically, as shown in FIG. **49**, the optical fiber **20** is embedded into the groove **222** (optical fiber **220** mounting section) formed by the wirings **212** and the guide walls **218** under the wirings. When such optical fibers **220** having a Y branching section **23** are used, an optical module suitable for wavelength multiplexing is provided.

Embodiment 5 has been described for an exemplary case of a board with built-in optical transmission channel employing optical fibers. However, in place of the optical fibers, optical waveguides composed of plane waveguides (PLCs) may be used as optical transmission channels **220**. When optical waveguides composed of plane waveguides (PLCs) are used as optical transmission channels, a sub-

board provided with a plurality of grooves and a sub-board **210***a* shown in FIG. **42**(*a*) are prepared on the plane waveguide (PLC) side. Then, these sub-boards are stacked with each other by a predetermined method such as by using a positioning marker (see FIG. **42**(*b*)). This improves manufacturability. When wirings **213** are formed on the plane waveguide (PLC) side, or when the optical element **230** is mounted on the plane waveguide (PLC) side, fabrication and the centering problem are further simplified. Nevertheless, from the perspective of cost, the use of optical fibers based on the fabrication method of Embodiment 5 would be advantageous over the use of the optical waveguides composed of plane waveguides (PLCS).

Embodiment 5 has been described for the case that a single optical transmission channel is arranged in the thickness direction in each sub-board. However, the present invention is not limited to this. A plurality of optical transmission channels may be arranged in the thickness direction of the board. In this case, each sub-board has a configuration, for example, shown in FIG. **46**.

Embodiment 5 has been described for the case that a plurality of optical transmission channels are arranged also in the direction substantially perpendicular to the thickness direction of the board. However, the present invention is not limited to this. A single optical transmission channel may be arranged in the above-mentioned perpendicular direction.

Embodiment 5 has been described mainly for the case that guide walls are used as guiding means. However, the present invention is not limited to this. Recesses such as grooves may be formed on a sub-board formed in advance so that optical transmission channels may be arranged in the recesses. In this case, in comparison with the configuration of Embodiment 5 employing guide walls, accuracy can be somewhat poor in the centering for the optical connection. In spite of this disadvantage, without using the guiding means of the present invention, optical transmission channels may be arranged in predetermined sections such as grooves formed independently of the formation of the circuit patterns. In this case, the sub-boards are stacked with each other using a positioning marker or the like.

Embodiment 5 has been described for the case that the guide layers **216**-**217** are stacked on the wirings **212** so that the guide walls **218** are formed as shown in FIGS. **40** and **41**. However, the present invention is not limited to this. For example, the steps of FIGS. **40**(*d*)-**41**(*b*) may be omitted. In this case, the wirings **212** serve also as the guide layer **218**, and has a thickness sufficient for positioning the optical fibers **220**.

Embodiment 5 has been described for the case that a part of the circuit patterns and the guide walls **218** are formed simultaneously in FIG. **45**(*b*), and further that the guide layer **218** and the wirings **213** are formed in FIG. **45**(*c*). However, the present invention is not limited to this. For example, all the circuit patterns and all guide walls **218** may be formed in FIG. **45**(*b*). In this case, the circuit patterns and the guide walls have the same thickness.

Embodiment 5 has been described for the case that the board with built-in optical transmission channel of the present invention is provided with optical elements or the like. However, the present invention is not limited to this. For example, optical elements or the like need not be mounted, and such a structure is sufficient that permits mounting.

Embodiment 5 has been described mainly for the case that the optical element is a surface type light emitting or receiving element or a photo receiving element. However, the present invention is not limited to this. An edge-emitting or receiving element may be used.

The positioning markers (included in the circuit patterns) and the guide walls are preferably formed using the same mask.

As described above, in an example, a board with built-in optical transmission channel of the present invention comprises: a board; circuit patterns formed on said board and having a plurality of wirings; and a plurality of optical transmission channels embedded in said board. A plurality of said optical transmission channels are arranged in different hierarchies in the depth direction of said board. An optical element is arranged above an end portion of each of said optical transmission channels.

In an example, a part of said circuit patterns formed on said board and said optical element are preferably connected electrically to each other.

In a preferred embodiment, a groove is formed between said wirings so that said optical transmission channel is arranged in said groove.

In a preferred embodiment, said optical transmission channels in said different hierarchies is arranged within a single groove.

In a preferred embodiment, said board is formed by stacking a plurality of sub-boards. A groove is formed in each of said sub-boards. Said optical transmission channel is arranged in said groove.

In a preferred embodiment, a plurality of said optical transmission channels are optical fibers.

In an example, said board is preferably composed of a composite material containing resin and inorganic filler.

Said optical element is preferably a vertical-cavity surface-emitting laser.

In a preferred embodiment, the light-emitting surface of said vertical-cavity surface-emitting laser is opposing to the surface of said board. Said light-emitting surface has a plurality of light emission points.

In a preferred embodiment, said end of said optical transmission channel is cut into an angle of approximately 45 degrees.

In a preferred embodiment, an inclined surface for optically connecting said end of said optical transmission channel to said optical element is provided in the vicinity of said end of said optical transmission channel.

Space or a transparent medium is present between said optical element and an end portion of said optical transmission channel.

In an example, a data processing apparatus according to the present invention comprises: an above-mentioned board with built-in optical transmission channel; and a semiconductor element mounted on said board with built-in optical transmission channel.

In an example, a fabrication method for a board with built-in optical transmission channel according to the present invention comprises: a step of preparing sub-boards on the surface of which circuit patterns including a plurality of wirings are formed and in which optical transmission channels are arranged in a groove formed between said wirings; and a step of stacking said sub-boards.

In an example, another fabrication method for a circuit board with built-in optical transmission channel according to the present invention comprises: a step of forming a plurality of grooves in the surface of a board; and a step of arranging at least two optical transmission channels in the depth direction in each of said grooves.

In a preferred embodiment, said optical transmission channels are optical fibers.

In an embodiment, performed are: a step (a) of patterning a metal layer formed on a supporting board and thereby forming circuit patterns including a plurality of wirings; a step (b) of arranging an optical transmission channel (such as an optical fiber) between the wirings of said circuit pattern; a step (c) of depositing a material containing resin on said supporting board such as to cover said circuit patterns and said optical transmission channel; and a step (d) of removing said supporting board.

In a preferred embodiment, said step (a) includes: a step of preparing a supporting board and a metal layer formed on said supporting board; and a step of etching said metal layer using a mask corresponding to the circuit patterns.

In an embodiment, a step of forming walls used as a guide for arranging an optical transmission channel, in at least a part of said circuit patterns is further performed before said step (b).

In an embodiment, in said step (b), said optical transmission channel is arranged such as to contact with said supporting board.

In a preferred embodiment, said optical transmission channel is arranged between said wiring such as to contact with said walls.

In an embodiment, said material containing resin is a composite material containing resin and inorganic filler.

In an embodiment, the uppermost portion of said optical fiber is substantially in plane with the upper surface of said circuit patterns after said step (d).

In an embodiment, a step of mounting an electronic component electrically connected to said circuit patterns is further performed after said step (d).

The present invention has been described above with reference to the preferred embodiments. This description does not limit the scope of the present invention, and hence various modifications can be made.

An optical transmission channel board and a fabrication method for an optical transmission channel board according to the present invention simplifies the fabrication process. That is, a centering process between an optical element and an optical transmission channel is advantageously simplified or even avoided. Thus, the present invention is useful as a data processing apparatus or the like employing an optical transmission channel board. Further, in an optical transmission channel board according to the present invention, a centering process between an optical element and an optical transmission channel is advantageously simplified or even avoided. This reduces the fabrication cost advantageously. Thus, the present invention is useful as a fabrication method for an optical transmission channel board or the like. Furthermore, a board with built-in optical transmission channel according to the present invention permits optical connection with an optical element, and advantageously realizes efficient arrangement of a large number of optical transmission channels. Thus, the present invention is useful as a board with built-in optical transmission channel, a data processing apparatus, a fabrication method for a board with built-in optical transmission channel, or the like.

What is claimed is:

1. An optical transmission channel board comprising:
- an optical transmission channel;
- a retention board for retaining said optical transmission channel; and
- circuit patterns which are formed on said retention board and a part of which is used as an electric circuit,
- wherein said optical transmission channel is positionally regulated by said part of said circuit patterns,
- said circuit patterns are formed in a predetermined thickness along a thickness direction of said retention board, and
- said optical transmission channel is arranged in a middle of said circuit patterns serving as guide walls.

2. The optical transmission channel board according to claim **1**, wherein said optical transmission channel is arranged between said guide walls formed by said circuit patterns.

3. The optical transmission channel board according to claim **1** or **2**, wherein said optical transmission channel is arranged such as to contact substantially with said guide walls.

4. The optical transmission channel board according to claim **1**, wherein said optical transmission channel is embedded in said retention board, while an uppermost part of said optical transmission channel is substantially arranged in plane with an upper surface of said retention board.

5. The optical transmission channel board according to claim **1**, wherein said circuit pattern has a portion lower than an upper surface of said retention board.

6. The optical transmission channel board according to claim **5**, wherein said portion lower than an upper surface of said retention board is a land part.

7. The optical transmission channel board according to claim **1**, wherein said optical transmission channel is an optical fiber.

8. A data processing apparatus comprising:
- an optical transmission channel board according to claim **1**;
- at least one semiconductor element selected from a memory LSI and a logic LSI mounted on said optical transmission channel board; and
- a laser element and/or a photo receiving element mounted on said part of circuit patterns; wherein
- said optical transmission channel board has a plurality of said optical transmission channels.

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